COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

February 1951

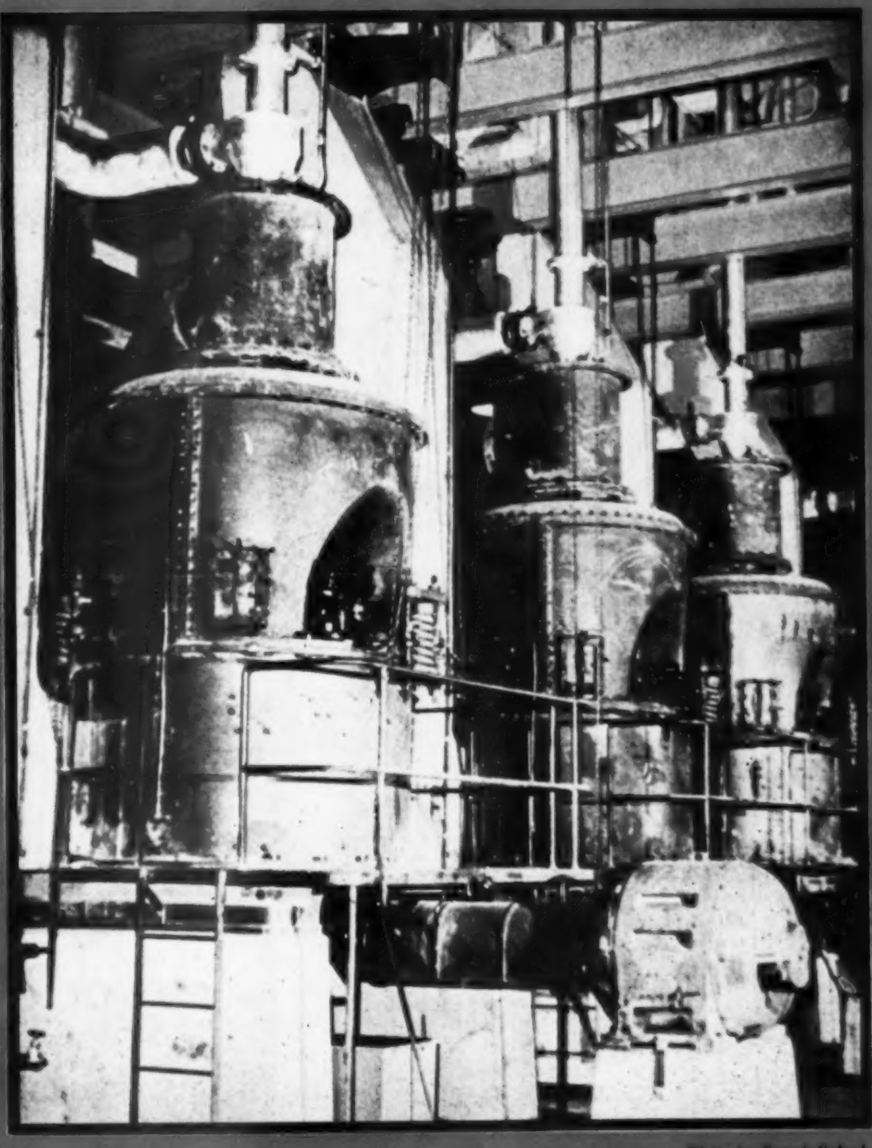

Photo by Frank Sobech

Titus Station of Metropolitan Edison Co.

Preferred Standards for 3600-RPM Turbine-generators

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Vol. 22 **No. 8**

February, 1951

Feature Articles

Editorials

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COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc.

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Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16

A SUBSIDIARY OF COMBUSTION ENGINEERING-SUPERHEATER INC.

Joseph V. Santry, President; Charles McDonough, Vice-President; H. H. Berry, Secretary and Treasurer

COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up and to consulting engineers in this field. To others the subscription rate, including postage, is $3 in the United States, $3.50 in Canada and Latin America and $4 in other countries. Single copies: 30 cents.

Publication Office, Easton, Pa. Issued the middle of the month of publication.

Acceptance under Section 34.64, P. L. & R., authorized by United States Post Office.

Printed in U. S. A.

COMBUSTION

Editorials

Professors in Industry

The need for closer working arrangements between engineering colleges and industry is a subject that has often been discussed. While there have been many instances of professors being employed in industry in a wide variety of engineering positions, seldom has there been a publicized invitation to do so. At the Second Industry-College Conference sponsored by the American Society for Engineering Education at Case Institute of Technology on January 20, Granville M. Read, chief engineer of E. I. du Pont de Nemours and Co., made a concrete offer to provide places for some professors to spend a year with that company.

Under the proposal the engineering teachers would be given experience throughout the Du Pont engineering department. Although specific details of how many are to be chosen, where they are to come from, and when, have not been worked out, those selected would receive their regular salaries plus reasonable expenses while in industrial employment.

Mr. Read pointed out that new scientific developments and discoveries have opened up many new fields in which engineers may practice their specialties. Engineering training may be made more valuable as more faculty members become aware of the viewpoints and problems of industry. With specialization increasing there arises an even greater need for a broad approach to problems. By providing an opportunity for engineering professors to come into direct contact with industrial practice Du Pont is setting an example which commends itself to much wider adoption.

A Step Toward Advancement of Nuclear Power

The Atomic Energy Commission has announced its acceptance of a proposal put forward by two well-known industrial groups to cooperate in the atomic energy program with a view toward developing nuclear reactors for the production of plutonium with the ultimate goal of producing electric energy. The initial agreement is understood to be confined to the study stage within the bounds of security requirements.

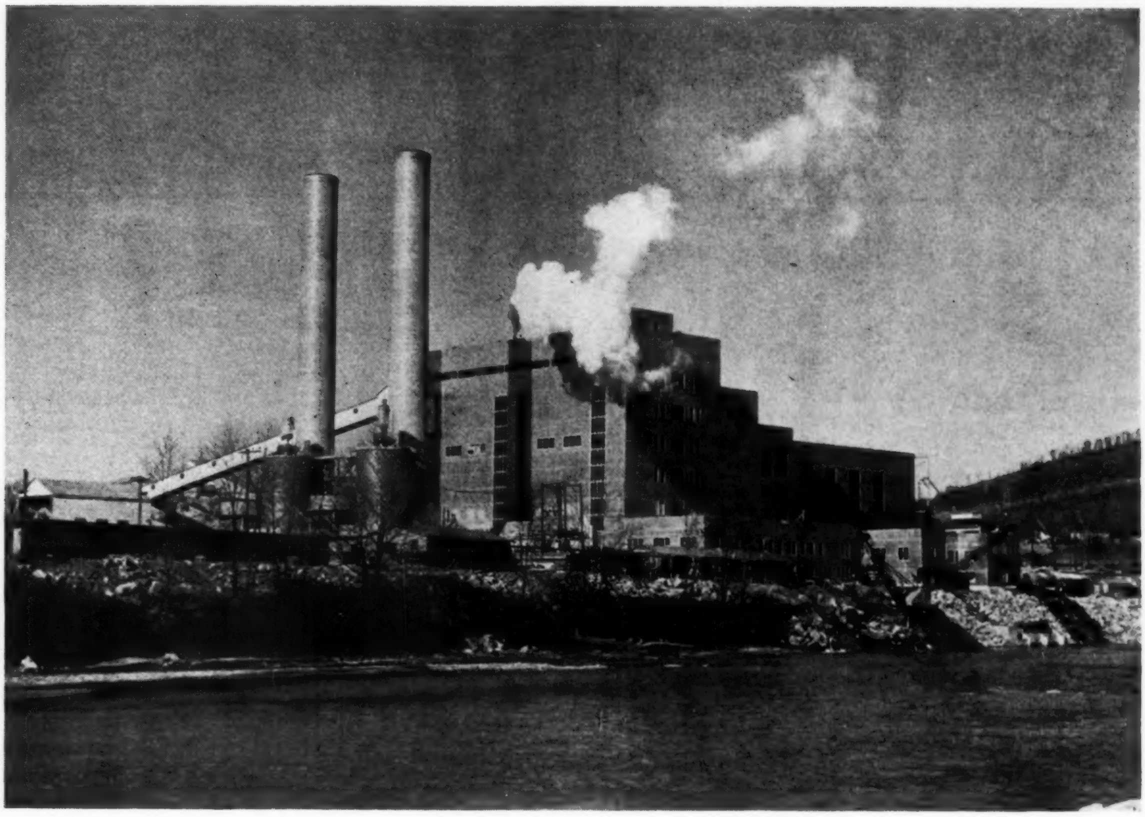
At a time when attention of the Commission is directed mainly at the defense program, this cooperative step should bring new technical and management resources into the general program which are likely not only to offer valuable assistance to the Commission in meeting some of its important problems, but also perhaps advance the time when electric power from nuclear energy will become an actuality. History teaches that out of the exigencies of every war have come material advances, usually as the result of industrial contributions to war efforts. The present case may fall in that category.

Private vs. Nationalized Coal Production

According to a recent broadcast sponsored by Bituminous Coal Institute, the 1950 record of government-owned British coal mines was most disappointing. Some twenty-one thousand coal miners left their jobs during the year and production lagged to the extent of seriously threatening the rearmament program, despite curtailment of lighting in some cities and of power in some less essential industries. In fact, Prime Minister Attlee is reported to have appealed for the production of three million extra tons of coal by April. Whereas Britain once was a large exporter of coal, she has lately been importing considerable from the United States.

While here in the United States we have long been plagued by periodic stoppages in coal supply due to labor troubles, of which last year was no exception, the total annual output measured well up to demand and stocks now on hand appear fully adequate. Moreover, the recent contract entered into voluntarily by the United Mine Workers and the bituminous coal industry, covering an increased wage rate, portends labor peace in that field at least till March 1952 and assures ample supply of coal to meet demands of the current emergency at an estimated price advance of 6 to 10 per cent at the mines.

It may be contended that the surprisingly reasonable attitude of Mr. Lewis on this occasion was influenced to some extent by the inroads made by fuel oil during the last stoppage, but it is undeniable that our privately owned and competitive mining industry is far more productive than the nationalized industry in Britain.



View of Titus Station nearing completion

TITUS STATION of the Metropolitan Edison Company

Features of this new 150,000-kw reheat plant are an aluminum paneled building, reflective insulation throughout, reheat to initial temperature of 1000 F and use of fly ash as an admixture in the concrete for foundations and flooring. There are two turbine-generators each served by a single pulverized-coal-fired steam generator.

By **J. G. Miller**
Supt. of Production, Metropolitan Edison Co.

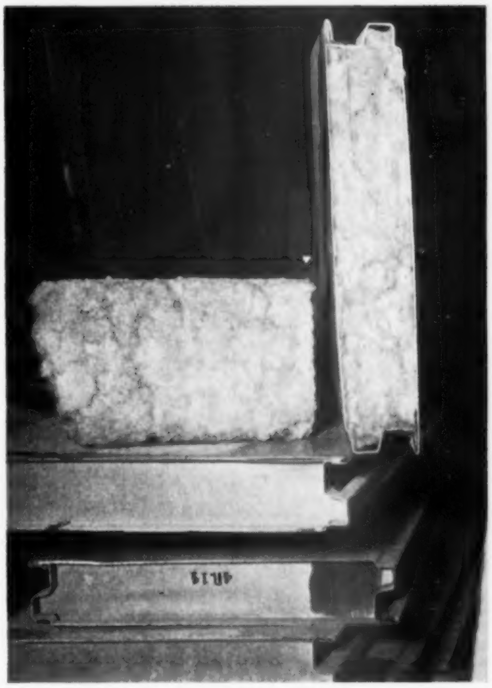
and **T. Y. Mullen**
Sponsor Engineer, Gilbert Associates, Inc.

ERECTION of Titus Station was started early in 1948 as a major expansion program of the Metropolitan Edison Company to meet the rapidly growing power demand of the area served in Eastern Pennsylvania. The initial installation includes two 60,000/75,000-kw units and the overall cost will approximate $24,000,000. A third unit, identical with the first two, has been authorized and is expected to be completed in 1953, bringing the capacity to 225,000 kilowatts.

The Station is located approximately two miles south of the city of Reading, Pa., on the Schuylkill River, the site having been chosen because of good railroad facilities, its accessibility by highway, and because of its proximity to the load center of the Metropolitan Edison system and its substation at South Reading.

Building Construction

In order to keep building costs to a minimum, several arrangements and types of building materials were studied, including a semi-outdoor station and a completely enclosed station with different types of wall materials. The arrangement incorporated in the final design includes a building enclosing all equipment except the river screens and trash racks, dust collectors and ash-collecting equipment. The building walls are aluminum C-panels manufactured by the Detroit Steel Products



Detailed view of aluminum C-panel

Company. These are 16 in. wide and 8 ft long and consist of two aluminum sheets 3 in. apart with glass wool filler. The panels are supported on special aluminum extrusions which, in turn, are supported by channel girts fastened to building steel.

Special tests using fly ash as an admixture in concrete showed that considerable cement could be saved on the station foundations, mats, etc., and an improved concrete obtained. Consequently, all the concrete contains fly ash. The mix used and some compressive strength test results are as follows:

Cement	470 lb
Sand	1400 lb
Stone	1850 lb
Added water	34 gal
Fly ash	100 lb
7-day compressive strength	2260 psi
28-day compressive strength	3790 psi
1-year compressive strength	5500 psi

Fly ash was also used in the fill between the mat and floor; the proportion used and the 7-day and 28-day strength being as follows:

Cement	188 lb
Sand	1400 lb
Stone	1820 lb
Added water	35 gal
Fly ash	400 lb
7-day compressive strength	520 psi
28-day compressive strength	1330 psi

Approximately 1500 tons of fly ash was used. No trouble was experienced in pouring the concrete and segregation was reduced by the use of fly ash. The appearance of the finished product is excellent and the color is only slightly darker than concrete without fly ash.

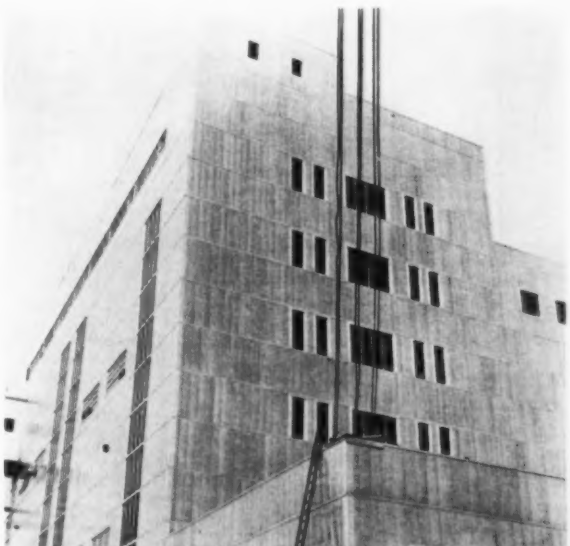
General Plant Layout

Since the plant is located in a rural area and ground costs were not excessive a lateral layout was followed in preference to vertical building design. This permitted the fan bay to be located at grade, and considerably simplified the problem of installing mechanical dust collectors. At the same time it provides for the future installation of electrostatic precipitators, if this step should become necessary.

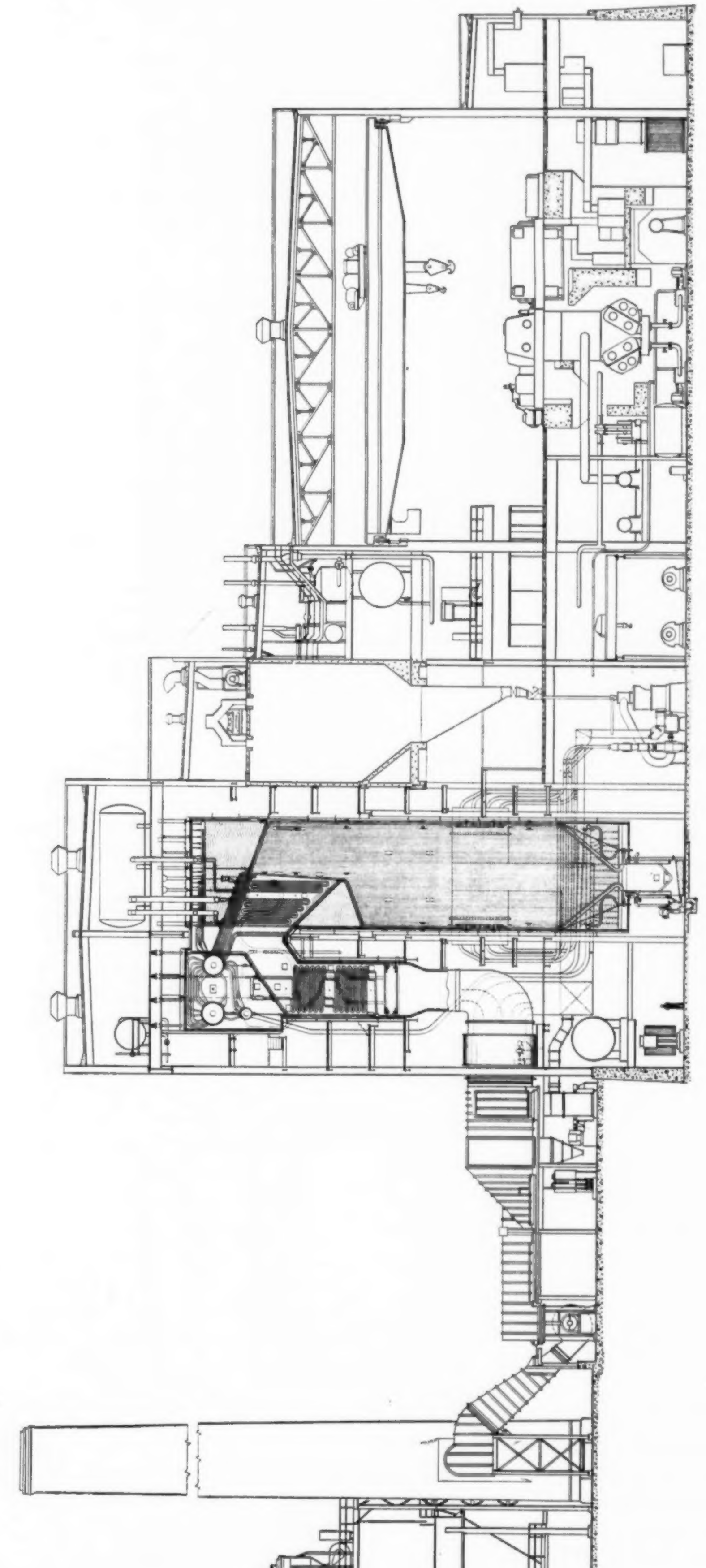
Layout was further influenced by the necessity for clarification of the river water before its use for the cooling of turbine oil, bearing cooling, pump seals and for miscellaneous power plant uses. In order to simplify operation of the water-treating equipment and to minimize the labor and dust resulting from handling of chemicals, the chemical storeroom was located adjacent to the railroad siding. This storeroom was placed immediately above the chemical laboratory and the dry feeders for the precipitators, and its floor is at an elevation corresponding to the height of the floor of the freight cars in which the chemicals are received.

Chlorination equipment is located in an isolated room, adjacent to both the chemical laboratory and the intake, thus achieving centralization of all major water-treating equipment around the chemical laboratory while maintaining maximum functional convenience.

Instruments and controls for two units are being installed at this time. These, together with equipment for the third unit, the addition of which will represent the plant's contemplated ultimate capacity, are provided for in a central control room. This room includes panels for controlling boilers, ash handling, soot blowing, turbines, generators, hydrogen-cooling system, generator switchboards, and miscellaneous pump and level controls. It is located on the operating floor between boiler No. 2 and turbine No. 2 and direct access is provided from it to both the turbine and boiler rooms.



Close-up of building showing aluminum panels



Sectional elevation through station

Mechanical Equipment

The station is arranged on a unit system basis, two complete units being included in the present installation. Each 60,000/75,000-kw turbine-generator of General Electric design, is served by a single Combustion Engineering-Superheater reheat-type steam generator capable of delivering 510,000 lb per hr of steam at 1475 psig pressure, 1010 F at the superheater outlet, and reheating 465,000 lb per hr of steam from 407 psig, 710 F to 383 psig, 1010 F. Firing is with pulverized bituminous coal by 16 tilting-type tangential burners which are served by four C-E Raymond pulverizers.

Temperature of the reheated steam is controlled by tilting the tangential burners to vary the rate of the heat absorption by the furnace wall tubes. A spray-type desuperheater is provided at the reheater inlet to serve as emergency reheat control. The initial superheated steam temperature is affected primarily by the tilting of the burners but supplementary control is achieved by twin-spray-type desuperheating stations located between the primary and secondary superheaters.

The steam generators are equipped with automatic sequential soot blowers, using compressed air as the blowing medium. Two constant-speed vane-controlled forced-draft fans and two dual-speed vane-controlled induced-draft fans serve each unit. A mechanical-type dust collector has been installed between the economizer outlet and the induced-draft fan inlets for each unit, with provision having been made for the future installation of electrostatic precipitators.

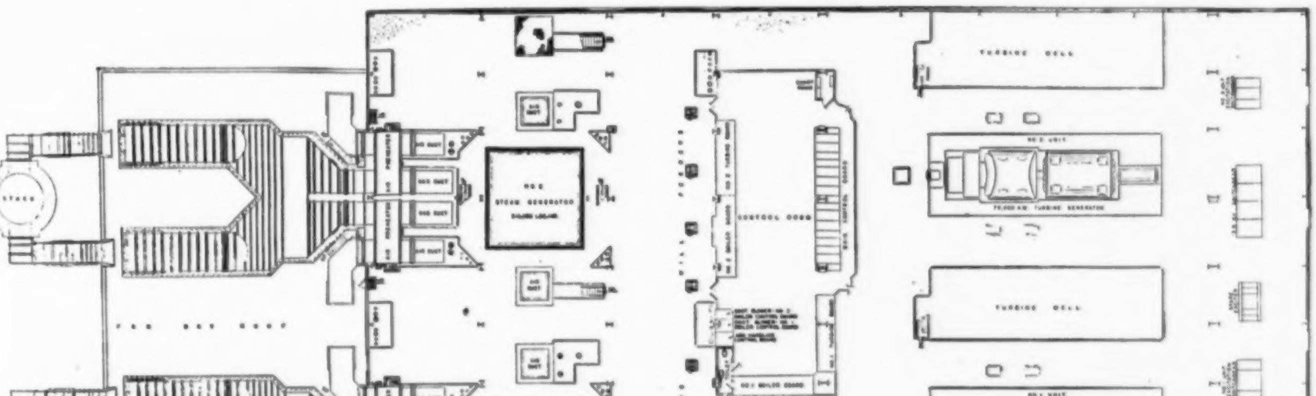
The feed system includes one low-pressure closed feedwater heater; one open-type deaerating heater, two full-size boiler feed pumps, driven through hydraulic couplings by constant-speed motors, and three closed-type high-pressure heaters. All closed feedwater heaters have integral drain coolers. The evaporator discharges its vapor into the deaerating heater.

Feedwater regulation is achieved by electronic control of the hydraulic couplings of the boiler feed pumps. No feedwater level control valve is installed between the pumps and the economizer.

Coal and Ash Handling Systems

Coal is received at the plant via the Reading Railroad and is unloaded at rates up to 900 tons per hour by a rotary car dumper which discharges to a concrete hopper. From this hopper coal is fed to an inclined belt conveyor by two dual-speed reciprocating feeders, at rates of either 450 tons per hour or 900 tons per hour. The inclined belt feeds either a stocking-out belt conveyor at the rate of 900 tons per hour, a Bradford breaker at the rate of 450 tons per hour, or a combination of the stocking-out conveyor and the Bradford Breaker at the rate of 450 tons per hour each. The breaker discharges 3-in. and smaller coal at the rate of 450 tons per hour to a horizontal feeder belt conveyor which discharges to a hammermill-type crusher. This crusher reduces the coal to $1^1/_4$-in. maximum size. It then is carried by a series of inclined belts, at the rate of 450 tons per hour, to a horizontal belt conveyor equipped with a tripper and dust-seal, located above the bunkers.

The coal-handling equipment was sized on the basis of providing sufficient capacity to supply the ultimate station without handling coal more than five days per week and without operating the equipment more than one shift per day. The bunkers have been designed to permit



Plan of station at operating level

the boilers to be operated over week-ends without operation of the coal-handling equipment.

Pyrites discharged from the pulverizers are collected by slow-speed screw conveyors located at the basement floor and delivering to a central storage pit. Ashes are collected in a flooded hopper below each furnace and are periodically sluiced to a common ash sump from which they are pumped to either of two hydro-bins. Pyrites are similarly sluiced from the collecting pit to the ash sump and then pumped to the hydro-bins by the ash pumps.

Fly ash is removed automatically from the soot hoppers by a pneumatic handling system which discharges to either of two silos located adjacent to the hydro-bins. Fly ash leaving the silos passes through rotary mixers which add sufficient moisture to permit trucking without causing dust. Ash from the hydro-bins is decanted and trucked to the points of disposal. Water lines to the outdoor ash-handling equipment are traced by electric heating cables and covered by reflective type insulation which serves as an ideal medium for distribution of the heat from the cable to the entire exterior surface of the pipe.

All water used for handling ash or for producing vacuum for the pneumatic dust-handling system passes through a supplementary settling basin before being returned to the river. This basin is periodically emptied by an overhead crane equipped with a clamshell bucket.

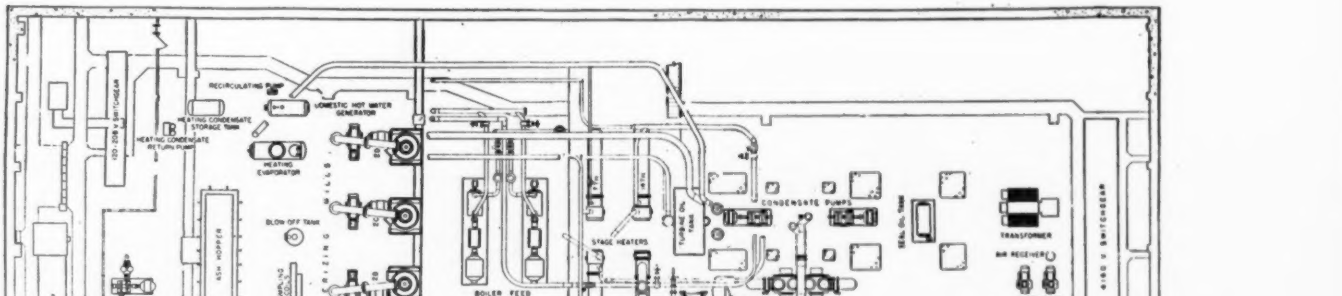
The main steam and reheat steam lines are fabricated of forged and bored $2^1/_4$ per cent $-$ 1 per cent molybdenum steel pipe. All piping and valves with the exception of special fittings and equipment connections have welding ends, the turbine manufacturer having welded short chrome-molybdenum nipples to the turbine stop and intercept valves at the point of connection to the customer's piping.

All high-pressure valves have pressure-sealed bonnets, and boiler stop valves were provided for each unit at the direction of the Pennsylvania Department of Labor and Industry.

Rubber-seated butterfly valves were substituted for gate valves in the circulating water piping, on the suction side of house service, precipitated-water, and raw-water pumps, and for low-pressure services on the water precipitators.

Reflective Insulation Employed

Titus Station is the first to employ reflective insulation throughout. This insulation is constructed of a series of aluminum alloy sheets, separated at intervals by spacer blocks providing multiple dead air spaces. It has been used on all power plant piping, feedwater heaters, tanks, hot-air ducts, breechings and fans, where other types of insulation are normally employed. It also was used for outdoor service and as an anti-sweat material as well as for heat-retention service. This material has several



Basement plan showing certain auxiliaries

advantages over other types of insulation. One is the elimination of the constant dust and dirt nuisance and consequent construction cost for clean-up which normally occurs throughout the erection period for other types of insulation. A second advantage lies in its suitability for removal and replacement, with a minimum of dirt, cost and labor during maintenance periods. Its fireproof quality, its construction which provides for expansion and contraction without cracking, and its appearance which eliminates the cost of painting are additional features which favored its selection.

The turbine-generators are the first of this size to be built by the General Electric Co. for 1450 psig, 1000 F throttle conditions and 1000 F reheat. The first unit has accordingly been equipped with a full compliment of test instruments and thermocouples in order that accurate performance data may be obtained.

Water Supply

The condensers are of two-pass divided water box design, and are equipped with motor-operated reversing valves to permit backwashing the tube sheets without taking half of a condenser out of service. Circulating water is taken from the Schuylkill River, and passes through mechanical trash rakes and traveling screens located outdoors before being intermittently chlorinated and entering the two horizontal centrifugal circulating pumps which serve each unit.

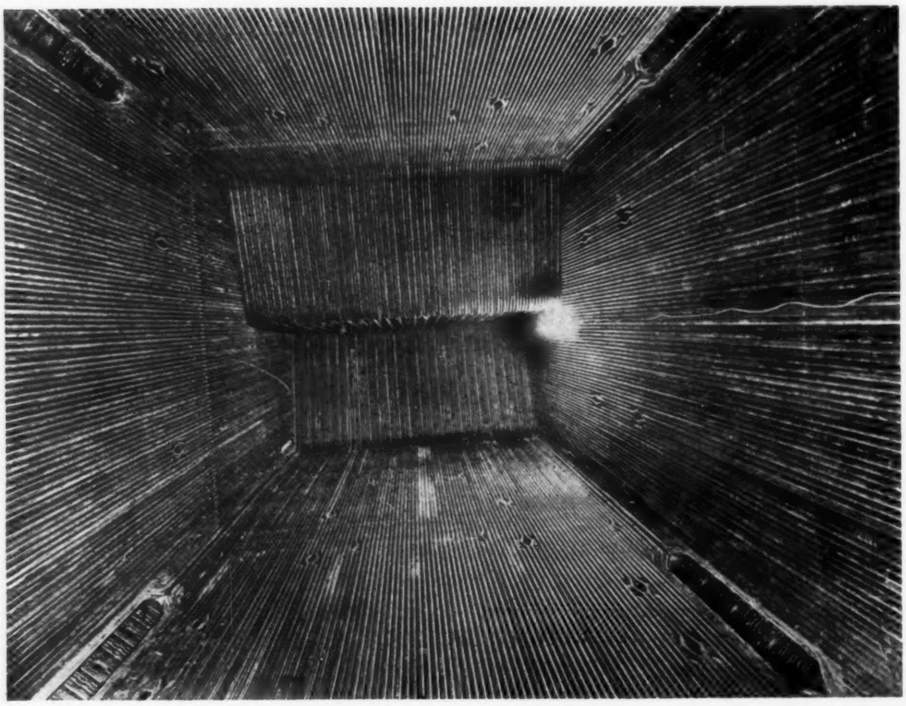
Water for drinking and sanitary purposes is procured from a deep well located under the plant storeroom. This water is continuously chlorinated and provision has been made for future installation of a softener if this should be found desirable.

Water for all other services is obtained from the Schuylkill River. It is normally quite turbid and contains a high amount of suspended solids, even though the Commonwealth of Pennsylvania is at present completing extensive clean-up work in this river. Two coagulating-type precipitators were therefore installed to clarify all water which is to be used in cored sections of castings, heat-exchangers, gravity-type filters or any other locations where settlement of the solids would tend to accumulate or cause abrasion to the detriment of the equipment. Each precipitator has sufficient capacity to reduce the turbidity of 2100 gpm of river water to 10 ppm, and is capable of providing enough precipitated water for the ultimate station capacity. All water entering the precipitators is chlorinated as it leaves the intake tunnel, in order to minimize the growth of micro-organisms. Three 100-gpm capacity, gravity-type filters were installed to provide highly clarified water for the ultimate plant, and two 100-gpm zeolite water softeners supply softened water to the evaporators.

Combustion control equipment was supplied by Leeds & Northrup Company and direct-current motors are used for all drive units.

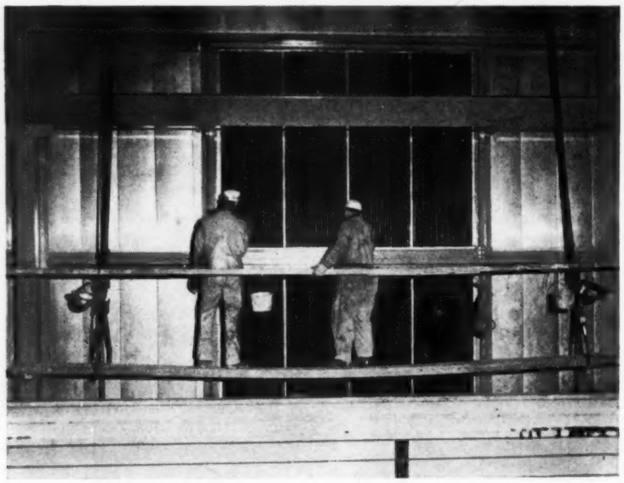
All flowmeters are of electronic design and pressure and temperature compensation features are included in the reheated steam-flow meters, steam flow-air flow meters, feedwater meters and evaporator vapor-flow

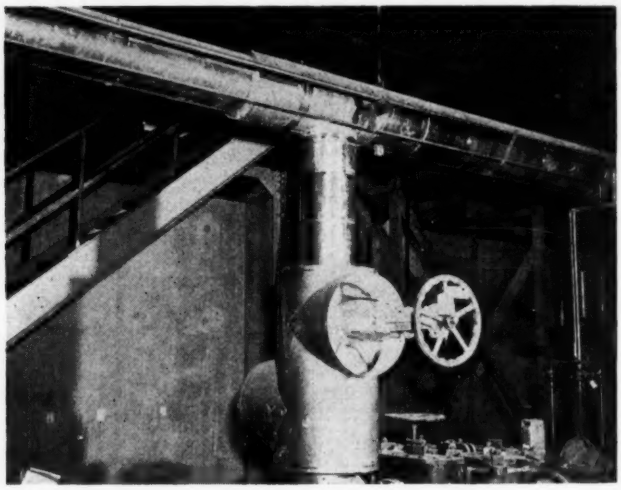
Coal-handling system



Furnace of boiler No. 1 showing tangential burners

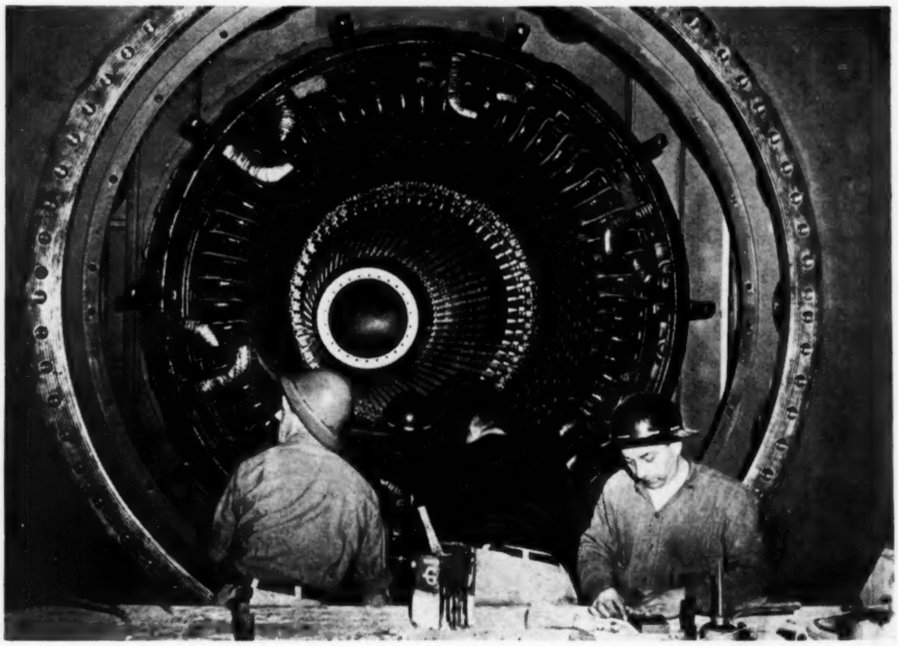
Piping and valves are covered with reflective insulation





Interior view of aluminum panel wall

Stator of No. 1 generator



Inclined coal-belt conveyor

meters. Temperature compensation is achieved in most cases by direct control from L & N temperature recording instruments.

Electrical Equipment

Each generator has a nominal rating of 60,000 kw at 0.80 power factor when operating at a hydrogen pressure of 0.5 psig, and a maximum rating of 75,000 kw at 0.87 power factor when operating at a hydrogen pressure of 15.0 psig. The generators deliver 3-phase, 60-cycle alternating current at 13,800 volts, and each unit is equipped with a gear-driven 1800-rpm exciter. One motor-generator set serves as a spare exciter for both generators.

An amplidyne generator was installed for each unit to provide automatic voltage regulation.

All station auxiliaries are motor-driven and the station service buses for each unit are normally supplied through a 7500-kva station service transformer connected directly to the generator leads. Emergency feed is provided by an underground cable from the 13,800-volt bus at the South Reading substation. This cable is normally energized and arranged to restore service automatically through a standby 7500-kva transformer to the auxiliaries of either unit in the event of loss of the normal source of supply.

The 7500 kva transformers serve 4160-volt buses which provide power to all motors 175 hp and larger. This voltage is stepped down to 480 volts for all motors from 25 to 150 hp in size, and is further reduced to 120/208 volts for plant lighting and for motors from fractional horsepower to 20 hp in size.

The 13,800-volt bus is normally split with the No. 1 generator supplying the 66,000-volt system through two 43-mva, three-phase transformers, and the No. 2 generator supplying the 114,000-volt system through two 43-mva, three-phase transformers.

The net station output is delivered by overhead 66-kv and 114-kv lines to the South Reading substation, which is located approximately one-half mile southwest of the plant site.

Power supply cables are armored and laid in cable trenches in the basement floor. Short runs of conduit are employed to carry these cables to individual pieces of equipment located near the trenches, and to the auxiliaries in the fan bay and in the coal-handling area. The trenches are covered with locked metal plates.

Motors have been equipped with oversize conduit boxes to facilitate making of cable connections, and to minimize difficulties which have been previously experienced with the smaller conduit boxes normally supplied as standard equipment.

The control cables are laid in sheet-metal troughs immediately below the operating floor. These troughs have metal covers, and conduit is employed to distribute the control cables from the points where they leave the troughs.

Engineering was performed as a cooperative effort by the Metropolitan Edison Company and Gilbert Associates, Inc. Preparation of plans and specifications, purchase of all apparatus and equipment, and general supervision of construction was carried out by Gilbert Associates, Inc., Reading, Pa.

Fireside Deposits Minimized by Humidification of Combustion Air

Following is an abridgment of a paper presented at the 1950 A.S.M.E. Annual Meeting describing how increasing the humidity of combustion air to at least 16 lb of water per 1000 lb of dry air was found to reduce greatly the fireside deposits in stoker-fired steam generators at the Delray Plant. It is believed that the improved boiler efficiency compensates thermally for the water added and there is a pronounced gain in availability and lower maintenance.

By PAUL MURPHY, JR., J. D. PIPER and C. R. SCHMANSKY

OF The Detroit Edison Company's steam generators, three at the Delray Plant have been plagued the most by fireside-deposit troubles, particularly in the superheaters. The table gives the features that are of the most significance to the present discussion. Two of these steam generators were placed in operation in 1938 and the third in 1939.

Within a few days after being placed in operation, the front loops of the superheaters became fouled with sponge-ash and shortly thereafter with hard deposits. Early efforts to overcome deposit troubles consisted of damper and baffle changes, changing the nozzles of integral soot blowers to pass twice the original amount of steam, changing from saturated to superheated steam in these blowers, and using telescopic soot blowers in the superheater area. None of these measures corrected the situation. Use of the integral soot blowers, which were fastened in fixed positions, was discontinued in 1940 because their use seemed to erode the tubes.

SUMMARY OF SIGNIFICANT DESIGN FEATURES OF DELRAY STEAM GENERATORS, NOS. 7, 8 AND 10

	Normal Full Load		Emergency Maximum Load
Steam output, lb/hr	344,000		424,000
Steam press., psig	865		865
Steam temp., F	910		910
Coal-burning rate, lb/hr	34,000		44,000
Gas temp. lv. superheater, F	1,080		1,160
Gas temp. boiler outlet, F	1,036		1,105
Gas temp. lv. economizer, F	498		530
Gas temp. lv. air heater, F	315		337
Air temp. lv. air heater, F	334		357
Heat release, Btu/cu ft	15,800		
Extended grate area, sq ft		611	
Effective heating surfaces, sq ft			
Water walls		4,622	
Convection boiler		7,035	
Superheater		11,275	
Economizer		17,760	
Air heater (vert. tube type)		28,008	
Furnace volume, cu ft		27,500	

Stoker: Single-ended Taylor underfeed, 15 retorts wide and 57 standard tuyères long. Actually use 82 thinner tuyères.

Superheater: Front three loops chrome molybdenum alloy steel. Tubes on 3.3-in. centers; OD $2^1/_2$ in., except in front loops in which tubes are swaged down to $1^3/_4$ in.

Four additional steam generators, similar to the three mentioned, except that the $2^1/_2$-in. front superheater tubes were on 7-in. centers instead of 3.3 in. and that the effective area was increased from 11,275 to 12,575 sq ft, were placed in operation between 1940 and 1942. The wider spacing reduced the tendency for "bridging-over" but otherwise did not affect deposit formation. Even when the telescopic soot blowers were used once an 8-hr shift, periods of availability were short for all seven steam generators, often less than 30 days in winter but sometimes two to three months in summer. In addition to superheater fouling, considerable fouling also occurred in the economizers and air preheaters.

Until recent years, three other troubles aggravated and confused the problem of fireside deposits. One of these was the interruption of coal fed over the stoker when wet coal was being used in winter, often causing blowholes through the fire. Another was secondary combustion in the superheater region, and the third was superheater-tube wastage. Samples of deposits removed from a superheater in 1945 were found by X-ray diffraction analyses to contain $K_3Fe(SO_4)_3$, as well as solid solutions of sodium and potassium sulfates. Chemical analyses had shown the deposits to be rich in SO_3, K_2O, Na_2O, and SiO_2.

Experimental Results

Two experiments, designed primarily to overcome the problems of secondary combustion and superheater-tube wastage but having a bearing on the fireside deposit problem, were carried out in 1944 and 1945. In one experiment, use of overfire air practically eliminated secondary combustion but did not reduce deposition of solids. Less sponge-ash was found on the superheater tubes but a very heavy scale formed and plugged the superheater. In the other experiment, superheated-steam jets were used above the fuel bed in half of a furnace to improve turbulence. Use of the steam reduced but did not eliminate secondary combustion. It reduced deposition of solids to a minor degree. Sections of the superheater in the half of the furnace in which the steam was used were noticeably cleaner than in the other and slight improvement was noticed in the economizer; but the improvement was not sufficient to justify the cost.

Gradually the problems of secondary combustion, superheater-tube wastage, and stoker blocking by wet coal were partially eliminated. Troubles from fireside deposits, however, remained as a vicious cycle in which fouled heating surfaces caused higher preheated-air temperatures, which in turn caused stoker-iron burning and increased fouling. Many possible solutions were tried and others considered. Use of lime, both as a solid addi-

All the authors are with The Detroit Edison Co.

tive to the fire and as a slurry to cover cleaned heating surfaces, was a failure. Small-scale experiments with coatings of graphite and aluminum, applied as paints to superheater tubes, showed these materials also to be ineffective in preventing formation of superheater deposits or in facilitating their removal. The only improvement in boiler availability came through better cleaning by a combination of scraping, blowing, sandblasting, and alkaline-water washing. Improvement in availability was only slight.

Evolution of the Humidification Method

Early in 1949, decision was made to attack more systematically the problem of fireside deposits at Delray. The investigation proceeded along two lines. One dealt with the relationship between the problem as it existed at Delray and experiences of others with fireside deposits. The other line of investigation dealt with the evaluation of a suggestion first made in 1944 that humidification of combustion air might reduce fireside-deposit troubles.

Chemical analyses of deposits removed from the superheaters at Delray early in 1949 showed the deposits to be of the alkali-matrix type. Published literature seems fairly well agreed that alkali-matrix deposits are more prone to form in stoker-fired plants than in pulverized-fuel-fired plants. Sodium, potassium and sometimes lithium compounds reportedly volatilize or are carried by flames from the fuel bed, and condense upon cooler surfaces, particularly the superheater tubes. There, these compounds react with sulfur trioxide to form, at superheater temperatures, sticky, semi-fluid sulfates, bi-sulfates and pyrosulfates.

Volatilization of solid-forming materials appears not to be limited to alkali-metal and sulfur compounds, as

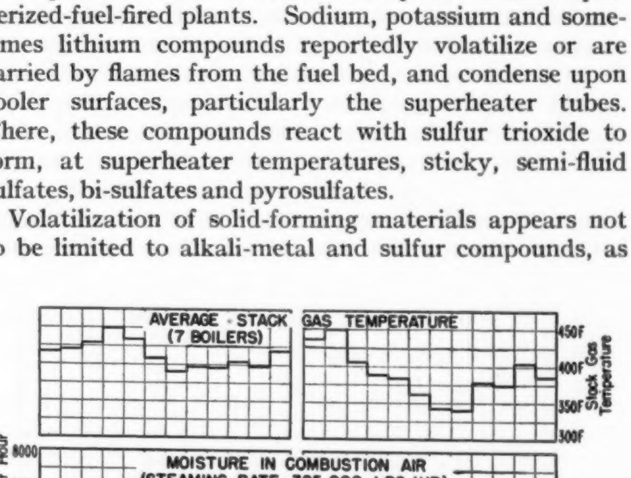


Fig. 1—Correlation between amount of moisture in combustion air, and stack gas temperatures and boiler room efficiencies

there is also evidence that certain compounds of phosphorus, boron and vanadium are selectively volatilized from the fuel bed.

Because the most troublesome deposits at Delray were in the superheater and appeared to be of the alkali-matrix type, means for combatting that type of deposit were sought from the literature. According to the British Boiler Availability Committee one of the best methods of combatting alkali-matrix deposits is to clean all heating surfaces thoroughly when the unit is shut down. Steam soaking and steam-and-ammonia soaking have been advocated for loosening alkali-matrix deposits. Small scale experiments showed these methods to have little if any advantage over alkali-water washing for removing deposits in Delray superheaters.

A second method advocated by the British Boiler Availability Committee to combat alkali-matrix type deposits in stoker-fired plants was directed toward reducing volatilization of alkali salts. The method con-

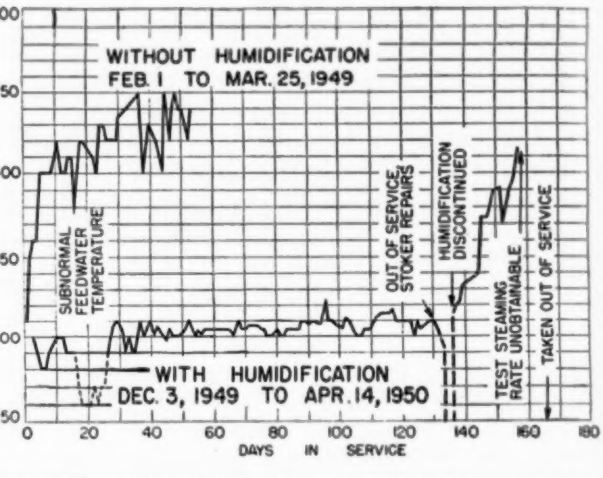


Fig. 2—Effect of humidification on stack gas temperatures measured at air-preheater outlet. Steaming rate of 325,000 lb per hr

sisted of using only those coals in which the concentration of alkali halides was low; less than 0.15 per cent chloride. The coals used at Delray met that requirement, and were low in both sulfur and phosphorus.

A third method, also designed to minimize volatilization, was to keep the fuel bed temperatures as low as possible. Several British operators expressed, privately, the belief that the burning rate should not exceed approximately 40 lb of coal per square foot of grate area, in contrast to the 56 or 72 lb at Delray for normal full load and maximum emergency load, respectively.

A fourth method is based upon the theory of Harlow that the primary cause of all fireside deposits is the catalytic production of sulfur trioxide. According to this theory, sulfur dioxide is oxidized to sulfur trioxide on superheater and boiler tubes that are coated with ferric oxide. The sulfur trioxide unites with water and condenses on the air preheater, economizer and sometimes on the last bank of boiler tubes. His suggested solution to the problem is to minimize catalysis either by limiting the temperature of the heating surfaces or by using noncatalytic materials. Harlow's work and Tolley's have shown that the catalytic activity of steel surfaces is temporarily lessened by coatings of Fe_3O_4, lime, soda, carbon, aluminum and pulverized-fuel fly ash.

From the theories reviewed it seemed evident that the formation of alkali-matrix type of deposits on superheaters could be eliminated if either of the following could be prevented: (1) formation of SO_3; (2) volatilization of sodium and potassium compounds. Because the first possibility was already under extensive investigation by Harlow, it seemed more advisable to pursue the second.

To minimize volatilization of any material, several courses are open. One is to add a reactant that will render the product less volatile than the original material. Another is to reduce the time or temperature of heating. For a stoker-fired installation that is already constructed, the time of heating cannot be materially shortened. The possibility exists, however, that an endothermic reaction, notably the water-gas reaction, may be caused to take place in the fuel bed. The heat thus absorbed should be recoverable when the products of the reaction burn. If the burning takes place above the fuel bed, away from the ash, volatilization of ash constituents should be diminished. The further possibility is believed to exist that the moisture may serve as a reactant to decrease volatilization through hydrolysis reactions.

Correlation Between Atmospheric Humidity and Steam-Generator Behavior

For many years it had been known that superheater deposits formed more rapidly in winter than in summer at Delray. This phenomenon was often ascribed to the stoker troubles caused by the wet coal encountered in winter. In 1944 a suggestion was made that the difference between winter and summer behavior might be related to the difference in the amount of moisture in the combustion air of these two seasons. An early attempt to correlate the amount of moisture in combustion air with steam generator behavior was unfruitful. In 1949, however, the possibility of correlation was carefully analyzed. For a steaming rate of 325,000 lb per hr, the amount of water vapor per hour entering the fuel bed with the combustion air for the years 1948 and 1949 was computed from U. S. Weather Bureau data. The average value for each month was compared, as shown in Fig. 1, with the corresponding average monthly air-preheater outlet-gas temperature for the seven steam generators under discussion and also with the average monthly efficiency of the entire boiler room which includes five other steam generators that operate at 700 F and 400 psig. Correlation was striking as shown, especially for the 1949 data for which the periods of high humidity coincided with periods of low stack-gas temperature and high efficiency. Conversely, the periods of low humidity coincided with the periods of high stack-gas temperature and low efficiency. Moreover, computation showed that the amount of water vapor passing through the fuel bed in summer is sufficient to react with an appreciable percentage of the carbon on the fuel bed, provided the water actually does react with the carbon. In winter the amount of carbon that could react with the small amount of water present seems to be nearly negligible.

Decision was made to try a humidification run on Delray Steam Generator No. 7 which has the close superheater-tube spacing. The total input of moisture was arbitrarily set at nearly the maximum for summer conditions of 7000 lb per hr for a steaming rate of 325,000 lb per hr; that is, approximately 16.4 lb per 1000 lb of dry air. Because the amount of moisture in the atmospheric air changes rapidly, flexible control was provided for the experiment so that the amount of added moisture could be adjusted every hour to compensate for changes in the absolute humidity of the outdoor air. The moisture was introduced into the preheated air as saturated steam. The amount of moisture so added was adjusted for each 25,000-lb per hr change in steaming rate.

When this unit was shut down for installation of the humidification equipment, the external heating surfaces were given a routine scraping and alkali-water washing. However, they were not sandblasted. The economizer and air-preheater surfaces were fairly well cleaned but the less accessible superheater surfaces held the usual residual blue-gray deposits that are so difficult to remove.

The humidification test was started December 3, 1949. Shortly thereafter a similar humidification system was placed in operation in No. 10 steam generator which is nearly identical except that, part of the time, blast-furnace gas is burned. The second installation provided a means for studying variables of operation without jeopardizing the long-time run on No. 7. Except during the study periods air to No. 10 was humidified to the same degree as was that to No. 7.

Effect of Humidification on Performance

The effect of humidification on the performance of No. 7 is shown in Figs. 2, 3 and 4. Under normal winter operation without humidification, illustrated by the upper curve of Fig. 2, the stack-gas temperature rose from 300 to 400 F in 5 days, and then continued to rise at a slower rate to 450 F or more over the period in which it was possible to keep the steam generator in operation,

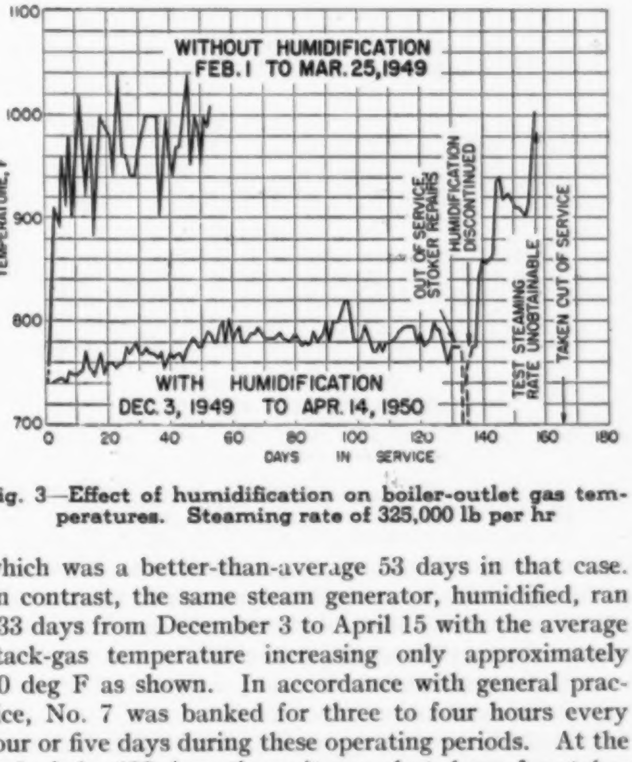


Fig. 3—Effect of humidification on boiler-outlet gas temperatures. Steaming rate of 325,000 lb per hr

which was a better-than-average 53 days in that case. In contrast, the same steam generator, humidified, ran 133 days from December 3 to April 15 with the average stack-gas temperature increasing only approximately 10 deg F as shown. In accordance with general practice, No. 7 was banked for three to four hours every four or five days during these operating periods. At the end of the 133 days the unit was shut down for stoker repairs. Without other alterations it was thereafter returned to service and operated without humidification. The stack-gas temperature rose rapidly as shown. During the 29 days of operation without humidification, the average input of moisture from the outdoor air was 2090 lb per hr for the 325,000-lb per hr rating used as a standard for the tests reported in the curves shown in Figs. 2 and 3. During the entire run the temperatures of the

preheated air were approximately 25 deg F above those of the stack-gas temperatures shown.

The effect of humidification on the boiler-outlet gas temperature is shown in Fig. 3. Without humidification the temperature rose from 740 to 960 F within 5 days and then increased in another few days to over 1000 F. With humidification the temperature rose approximately 50 deg F in the first 60 days of operation and then remained essentially constant. After humidification was shut off, the boiler-outlet gas temperature rose to over 1000 F within 21 days as shown.

During the entire 133 days of operation with humidification the steam generator was capable of steaming 400,000 lb per hr; after 24 days without humidification the maximum steaming rate obtainable was 300,000 lb per hr.

Observations made during the course of the test and at its conclusion showed that after 133 days with humidification there was less deposit on the front rows of superheater tubes than would have been deposited in 30 to 50 days without humidification. Beyond the fifth row the amount of deposit was negligible with humidification. The economizer was remarkably clean, much of the surface holding no deposit at all and parts where gas velocities were low holding only a very thin layer. The water walls and boiler tubes remained remarkably free of the white deposit that normally accumulates. The condition of the air preheater after the 133 days was approximately the same as would be found after 30 to 50 days without humidification.

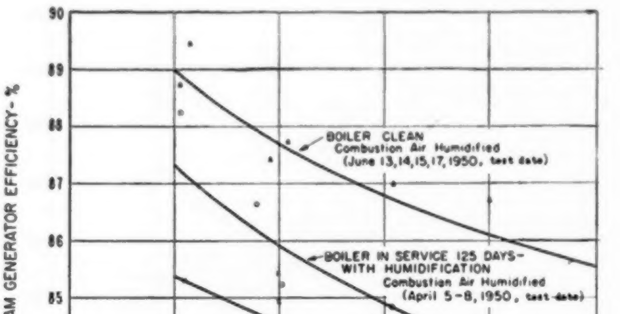


Fig. 4—Steam generator efficiency during humidification tests on No. 7 boiler. Efficiency computed from the following losses: Incomplete combustion loss, unburned carbon loss, radiation and convection losses, sensible heat loss in dry flue gas, moisture losses and auxilary power requirement

During the 29 days without humidification, following the 133-day run with humidification, the superheater fouled rapidly. The economizer, however, fouled at less than the normal rate for unhumidified conditions, becoming only moderately dirty.

Efficiency tests were made after 125 days of the 133-day humidification run, after 23 days without humidification, and after the steam generator had been thoroughly cleaned, including sandblasting, during the annual inspection period. The results of the tests are shown in Fig. 4. The several heat losses from which the efficiencies were computed are enumerated in that figure. They include the charge for stoker and fan-power requirements but do not include the charge for humidification. According to information available to date, the humidification requirements for Detroit climate will be 1.3 per cent of the steaming rate when averaged over an entire year. During the coldest part of the winter indications are that the requirements may be approximately 2 per cent.

It should be pointed out that further data will have to be obtained before the effect of humidification on boiler efficiency can be evaluated adequately. The top curve of Fig. 4 is believed to represent fairly well the efficiency of the clean steam generator operating with humidification. The center curve, representing the humidified steam generator after 125 days, may be low for two reasons: (1) the heating surfaces of the water walls, boiler, and superheater were not well cleaned before the start of the run; (2) the total carbon in the stack dust was unusually high during the course of the efficiency test, thus lowering the computed efficiency. Ash and sulfur concentrations in the coal used for that test were higher than for the other two tests. The values shown by the bottom curve are probably too high to be typical of a nonhumidified steam generator. As previously stated, the superheater was fouled to some extent after 133 days of operation with humidification while the economizer was remarkably clean. The accumulation that rapidly developed on the superheater after the humidification was discontinued apparently collected the materials that would normally have deposited in the economizer and air preheater. This would have the effect of producing lower air-preheater-outlet flue-gas temperatures than would normally have obtained during an operating period without humidification, and consequently an abnormally high efficiency. Until such time as more data are available it seems probable that humidification, through keeping heating surfaces cleaner, will improve average efficiency at least enough to compensate for the cost of its use, thus leaving a distinct gain through better availability and lower maintenance. The economic and engineering aspects of the problem are being further studied.

Summary

Addition of moisture to the combustion air used in the 910-F, 865-psig stoker-fired steam generators at Delray, to bring the total humidity of the combustion air to approximately 16.4 lb per 1000 lb of dry air, markedly reduced the rate of fouling in the superheater, economizer and air preheater. The amount of fouling in the economizer was practically negligible. To the present, data for only one long-time humidification test are available. From those limited data it seems probable that through use of humidification the average steam-generator efficiency is improved sufficiently to compensate thermally for the water used, leaving a distinct gain through better availability and lower maintenance. The gain in efficiency is believed to come from greater heat transfer caused by: (*a*) less thickness of heat-insulating deposits; (*b*) better radiation absorption by a dark-colored surface than by a light-colored surface.

Although long-time tests have not yet been made, short-time probe tests indicate that the extent of fouling of heating surfaces is an inverse function of the amount of water in the combustion air, at least up to 25 lb water

per 1000 lb of dry air. The optimum amount to use has not yet been evaluated economically. Presently it seems probable that the amount is near the 16.4 lb per 1000 lb of dry air that was used in the one long-time test.

The mechanism by which moisture, added to combustion air, reduces deposition on superheater, economizer and air preheater surfaces seems to be at least twofold: (*a*) selective volatilization of silicon compounds from the fuel bed is reduced; (*b*) general volatilization of all other constituents of ash is also reduced.

The silicon compounds that deposit on the heating surfaces are the materials of high reflectivity that probably cause the poor radiation absorption previously mentioned. These white materials are apparently amorphous silica. Selective volatilization of sodium and potassium compounds from the fuel bed, as claimed by previous investigators, seems confirmed. Whether humidification reduces the selective volatilization has not been proved; the amounts of these materials that collect on tube surfaces are, nevertheless, reduced presumably through reduction of general volatilization.

Limitations of Shielded Probes

It is recognized that use of the probe-tester shield to prevent impingement of solid particles does not insure that all materials that collect on the shielded probes actually volatilize from the fuel bed and condense on the probe. Nevertheless, the uniformity of the thickness, appearance and composition of the deposits suggest strongly that the iron and aluminum compounds, and the silica that is normally associated with them, reach the probes by the same mechanism as brings the sodium and potassium compounds. There seems to be a distinct possibility that the vapor pressure of the iron and aluminum silicates, although exceedingly low, is still high enough at fuel-bed temperature to provide transport for those materials to the tube. Possibly, however, these materials are carried by flames.

The phenomena that take place between the time the materials first deposit and the time they form hard layers has not yet been investigated. Part of the deposits collected on the upstream side of the unshielded superheater probes invariably stuck tenaciously even though the maximum surface temperature of the probe probably did not exceed 1125 F. Little, if any, sticking occurred with the shielded probes where the upstream surface, protected from the radiation by the shield, remained closer to the 950 F to 1000 F temperature of the thermocouple within the wall of the probe. In the superheater of the steam generators in question, the sticking phenomena seems to be related to the sintering behavior described in the literature. The sticking behavior of the economizer deposits may be related to an observation that the fluffy silica deposits, upon being moistened with acids and ignited to 500 F, become hard masses.

Presently it has not been proved whether the endothermic reaction mentioned in the theory actually takes place. Attempts to measure fuel-bed temperatures with and without humidification of combustion air have thus far been unfruitful. Much more investigation will be required before the phenomena involved are thoroughly understood.

Facts and Figures

Electric utilities consume about 20 per cent of the coal burned in the United States.

•

A gain of 4 to 5 per cent from reheating at 1000 F is nearly equivalent to that obtained by increasing the initial steam temperature from 1150 to 1200 F.

•

The British Ministry of Fuel and Power reports an average fuel consumption by electric utilities in England for 1949 as 1.39 lb per kwhr.

•

More than 90 per cent of the bituminous coal produced in this country is cut by machines.

•

The National Production Authority has limited the nonmilitary use of nickel in the first quarter of 1951 to 65 per cent of the average quarterly rate of consumption during the first six months of 1950.

•

Since V-J Day, strikes have cost the nation 29 million tons of steel.

•

Television has at last been applied to the furnaces of power boilers.

•

Chrome-molybdenum pipe is being employed to resist graphitization. For temperatures up to 975 F, 1 per cent Cr and 0.5 per cent Mo is said to be effective and for higher temperatures alloys containing 2 to 3 per cent chromium are used.

•

Natural steam from the earth at Larderello, Italy, which is being used for power production, comes to the surface at 220 to 265 psig pressure.

•

Manufacturers are reported to be turning out power generating equipment of all types at the rate of 6,855,000 kw per year.

•

Phosphoric acid is claimed to possess important advantages over hydrochloric acid for internally washing boilers.

•

Some of the largest steam generating units employ as much as 15 miles of tubing.

•

The highest steam temperature employed in marine practice is 1020 F.

•

It is possible to sample air for contaminants above stack top levels by means of "Kyfoons" (kite-balloons) drawing the samples to ground through polyethylene tubing for analysis.

•

With spreader stokers it is advisable to hold maximum continuous furnace heat-release rates in water-wall furnaces to 35,000 Btu per cu ft per hr.

•

It requires a ton and a half of coal to produce a ton of steel.

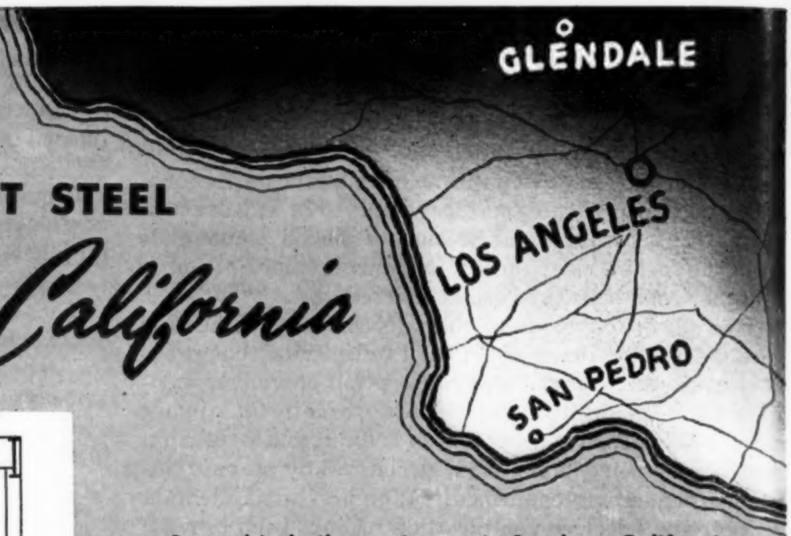
•

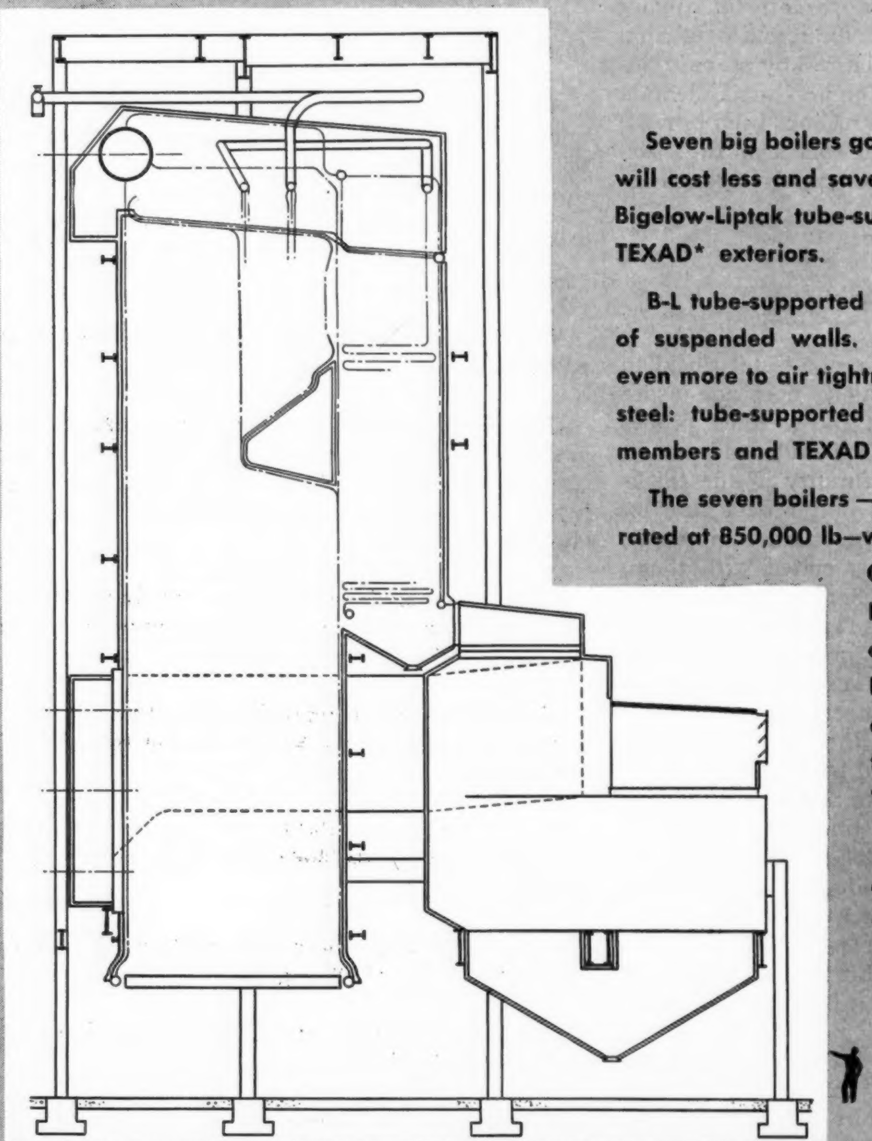
The first steam engine to operate in Pittsburgh was at a grist mill in 1808.

TEXAD*

SAVES HARD-TO-GET STEEL

in Southern California





Seven big boilers going up in Southern California will cost less and save steel because specs call for Bigelow-Liptak tube-supported wall enclosures and TEXAD* exteriors.

B-L tube-supported walls maintain the principles of suspended walls. Weatherproof TEXAD* adds even more to air tightness. Both developments save steel: tube-supported walls won't need structural members and TEXAD* eliminates plate.

The seven boilers — all over 100,000 lb and two rated at 850,000 lb—will be erected in Los Angeles, Glendale and at Terminal Island near San Pedro. In addition, one 400,000 lb boiler and a 100,000 lb unit are now in successful operation in Amarillo, Texas, and Waterloo, Iowa.

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Revised Preferred Standards for 3600-RPM Turbine-Generators

These standards, offered jointly by the AIEE and ASME, were extended as of last November to cover the 90,000/99,000 size for both the straight regenerative and the reheat cycles. The International Standards are also discussed.

By A. G. Christie‡

An article by this author in COMBUSTION for April 1945 presented a discussion of the "Preferred Standards for Large 3600-RPM, 60-Cycle, Condensing Steam Turbine-Generators." They had been prepared by a Joint Committee of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers. These early Preferred Standards covered certain sizes of units in the range of 11,500 to 60,000 kw rating. It was the consensus of the committee that it was inadvisable at that time to adopt any rating as standard greater than the 60,000-kw unit. This size was considered to be the largest economical rating with 20-in. last row blades and the largest rating on which there was sufficient operating experience. It was felt that later station developments and experience with 23-in. blades in the last rows would indicate the most desirable steam conditions and ratings for a unit of greater capacity.

Since 1945 certain factors have made desirable a revision of the earlier standards. Increased coal and labor costs encouraged the use of higher steam pressures and temperatures and of units of greater output. Available metals placed a limit on steam temperature and led to the use of the reheat cycle. Satisfactory operating experience with hydrogen cooling in generators made it desirable to extend the use of hydrogen to the 15,000 kw rating in place of air cooling.

Effective November 15, 1950, the two sponsor bodies of the Joint Committee (AIEE and ASME) issued a circular giving the new revised "Preferred Standards" together with Standard Specification Data on the Generators. The accompanying table is taken from this circular.

The two new large standard units are rated at 90,000 kw with 85 per cent power factor and having a turbine capability of 99,000 kw with $2^1/_2$ in. mercury absolute exhaust pressure. One unit has throttle conditions of 1450 psig, 1000 F. A different unit of the same rating is of the reheat type with throttle conditions of 1450 psig, 1000 F, and reheating at an intermediate pressure to 1000 F. The turbine-generator rated at 15,000 kw will have hydrogen cooling. Also, its initial steam conditions have been changed to 850 psig, 900 F, which conditions are desirable with fuel prices now prevailing.

Experience with hydrogen-cooled generators has shown that increased capacity of the generator may be secured by raising the hydrogen pressure to 15 psi, and generator capabilities at that hydrogen pressure with 85 per cent power factor, are also given in the table. The largest units have generators capable of operating with 30 psi hydrogen pressure and generator capability under this pressure and with 85 per cent power factor is also stated.

‡ Professor Emeritus of Mechanical Engineering, The Johns Hopkins University and member of Preferred Standards Committee.

CORRECTED TABLE FOR PREFERRED STANDARDS FOR LARGE 3600-RPM, 3-PHASE, 60-CYCLE CONDENSING STEAM TURBINE-GENERATORS

	Air-Cooled Generator	Hydrogen-Cooled Generator Rated for 0.5 Psig Hydrogen Pressure						
Turbine-generator rating, kw	11,500	15,000	20,000	30,000	40,000	60,000	90,000*	
Turbine capability, kw	12,650	16,500	22,000	33,000	44,000	66,000	99,000	
Generator rating:								
Kva	13,529	17,647	23,529	35,294	47,058	70,588	105,882	
Power factor	0.85	0.85	0.85	0.85	0.85	0.85	0.85	
Short-circuit ratio	0.8	0.8	0.8	0.8	0.8	0.8	0.8	
Throttle pressure, psig	600	850	850	850	(850 or 1250)	(850 or 1250)	(1450 or 1450)†	
Throttle temperature, F	825	900	900	900	(900 or 950)	(900 or 950)	(1000 or 1000)	
Reheat temperature, F								1000
Number of extraction openings	4	4	4	5	5	5	5	5
Saturation temperatures at openings at "turbine-generator rating" with all extraction openings in service, F								
1st	175	175	175	175	175	175	180	175
2nd	235	235	235	235	235	235	245	240
3d	285	285	285	285	285	285	305	300
4th	350	350	350	350	350	350	380	370
5th	...	...	...	410	410	410	440	440
Exhaust pressure, in. Hg abs	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Generator capability at 0.85 power factor and 15 psig hydrogen pressure, kva	...	20,394	27,058	40,588	54,117	81,176	121,764	
Generator capability at 0.85 power factor and 30 psig hydrogen pressure, kva.	...	...	...	...	...	...	132,353	

A tolerance of plus or minus 10 F shall apply to the above saturation temperatures. (Tolerances shall be unilateral so as not to reduce the spread in temperature between adjacent extraction openings.)

The "turbine capability" is guaranteed continuous output at generator terminals when the turbine is clean and operating under specified throttle steam pressure and temperature and $2^1/_2$ in. Hg abs. exhaust pressure, with full extraction from all extraction openings.

* A 10 per cent pressure drop is assumed between the high-pressure turbine exhaust and low-pressure turbine inlet for the reheat machine.
† These are two different units; the first for regenerative cycle operation, and the second a machine for reheat-cycle operation.

This generator capacity exceeds the capability of the turbine under normal conditions.

In selecting the rating of the new largest unit given in the table, the Joint Committee adopted as a general principle that this rating should be 50 per cent larger than that of the next lower sized unit. If a still larger unit with triple exhaust is adopted at a later date, it will probably be 50 per cent greater in rating than the 90,000-kw standard.

One may ask why only five extraction points were specified for the new 90,000-kw Standards. Many of the larger turbines recently installed have more than five extraction points. It was the opinion that it is generally difficult to justify the cost of more than five heaters with their added piping and valves, by the small incremental gains at average load factors from additional heaters and where fuel is available at average prices. Higher fuel costs may warrant the addition of more than five extraction heaters.

International Standards for Steam Turbine-Generators

The International Electrotechnical Commission was organized originally many years ago to fix standard electrical units for international use. In the intervening years, it expanded its functions and among other activities undertook the preparation of standards for Prime Movers and their generators. International committees were formed and became quite active during the nineteen twenties. In fact International "Specifications for the Purchase of Steam Turbines" and "Rules for Acceptance Tests" were completed by 1931 and on behalf of the United States, were officially adopted by the then American Advisory Committee.

That date fell during the depression and little publicity was given to these International documents. They appear to have had little influence on American steam turbine sales or development.

At the end of World War II, the International Electrotechnical Commission was reorganized and activities undertaken both here and in Europe. A new American Advisory Committee was appointed with the author as Chairman. Also, the American Committee was made Secretariat for Steam Turbines, i.e., this Committee initiates action and directs the International Activities concerning steam turbines.

In the meantime, Preferred Standards for Large 3600-RPM Condensing Steam Turbine-Generators had been adopted in this country. This adoption appears to have made a deep impression on European engineers for a request was made about two years ago by several of their National Committees that the Secretariat initiate action leading to similar standards for the 50-cycle steam turbine-generators used in all countries other than United States, Canada, Mexico and Japan. The American Advisory Committee felt a lack of experience with 50-cycle units and recommended that the European nations form a subcommittee to prepare 50-cycle standards. This subcommittee was organized about a year and a half ago and after several meetings certain standards were chosen.

Plans were made for a meeting of representatives of the several national steam turbine committees in London last July at which the American Committee was represented. The American Committee decided to request that the Preferred Standards for Large 3600-RPM Units as given in the accompanying table, be adopted as International Standards for 60-cycle steam turbines. However, difficulty arose over the definition of the capacity of steam turbines. The International Specifications define the rating of a steam turbine as "its guaranteed maximum continuous output at the alternator terminals when operating at the specified conditions as regards speed, steam inlet pressure and temperature, feedwater heating, exhaust pressure and re-superheating, if employed." This rating corresponds to what is known as "turbine capability" in America. To conform with international usage, the 60-cycle standards as in the accompanying table, had to be modified. The first line—"Turbine-Generator Rating, KW," was omitted and the second line "Turbine Capability, KW," changed to "Turbine-Generator Rating, KW." This explanation is given so that there will be no misunderstanding when the International Standards are finally published. The machines are the same in both American and International Standards, but the basis for expressing rating is different.

The saturation temperatures at extraction openings are at nominal rating as given in the table. In the International Table the same temperatures will appear but these will be specified as at 91 per cent of the International rating or at the same kilowatt load as in the American Table.

Much progress was made at the London meeting in fixing standards for 50-cycle turbine-generators. Steam conditions are comparable with those in the 60-cycle standards for the specified units. However, European engineers are not yet prepared to go as far as the American Standards in fixing extraction temperatures at a given load. Agreement on these temperatures may come later. Also, it was not possible to reach agreement on as many different sizes of units as in the American Table. This also may come later.

Both 50-cycle and 60-cycle International Standards are now being voted upon by the several National Committees and if accepted, will be given early publicity.

In the meantime, the American Advisory Committee, as Secretariat, will undertake direction of the revision of the International "Specifications for the Purchase of Steam Turbines" and "Rules for Acceptance Tests of Steam Turbines." It is hoped that these will be given greater publicity and use in this country than those adopted in 1931.

A.I.E.E. Winter Meeting

At the Winter General Meeting of the American Institute of Electrical Engineers held in the Hotel Statler, New York City, January 22–26, there were a number of items of general or specific interest to engineers in the steam power field. More than 3000 electrical, electronics and nucleonics specialists were present for the meeting.

The Hoover Medal, a joint award of the four founder engineering societies, was presented to **Dr. Karl T. Compton,** chairman of the board of the Massachusetts Institute of Technology. In an address entitled "Engineers and National Security" Dr. Compton declared that the discovery of men qualified to handle key posts in the present mobilization is the nation's number one problem. It is important that the business world seek out promising young men who may be tested in jobs of increasing responsibility. Although the public may think that money and Congressional action are what get things done, actually it is necessary to find people who are qualified to do the job. Dr. Compton expressed that thought as follows:

"There is a profound difference between dollars and men. All dollars, provided they are not counterfeit, are alike and interchangeable; men are not alike, and the more important and difficult the task for which they are needed the less are they interchangeable. . . . Any monetary bottleneck can be broken open if the emergency is serious enough to justify the means for doing it; there is absolutely nothing which can be done quickly to get around a basic dearth of human talent."

Dr. Vannevar Bush, president of the Carnegie Institution of Washington, D. C., was the recipient in absentia of the John Fritz Medal awarded by the four founder engineering societies "for outstanding scientific contributions to his country and to his fellow men." In a prepared acceptance address Dr. Bush declared that the need for engineers in the armed forces is important at the present. However, if they are called up in too great numbers, there is some danger of wrecking the very industry that is being put on a war production basis. He added that the immediate future cannot see us as both comfortable and happy and that engineers might take the initiative in suggesting the sacrifice of a few of our niceties in order to preserve our way of life for future generations.

Defense Against Military Attack

A panel discussion was presented on the subject of "Operation of Power, Communication and Transportation Utilities under Military Attack." **H. I. Romnes** of the American Telephone and Telegaraph Co. presided at the first session and stated that the purpose was to study means of repairing and restoring utility service after a military attack. Since utilities are accustomed to meeting emergencies of various kinds, their experience gained throughout the years should be valuable in getting facilities back into operation. However, normal emergency plans must be reviewed to see if they will cover extreme conditions such as may be encountered in atomic bombing.

Discussing physical structures and the destructive effects of atomic weapons, **W. E. Kelly,** manager of the New York Operations Office of the Atomic Energy Commission, described some of the conditions which might be encountered. Although many people attribute part of the extensive damage at Hiroshima and Nagasaki to inferior Japanese construction, the speaker pointed out that many of the buildings in those two cities were specially designed to withstand earthquakes. As far as basements are concerned, they are of little use as shelters unless reinforced, because of the danger of flying and falling debris. In clearing up after an atomic attack the bulldozer is probably the most important single piece of equipment in removing rubble and restoring road transportation.

Dr. Bernard S. Wolf, medical director of the New York Operations Office of the Atomic Energy Commission, stated that an atomic explosion would cause casualties due to (1) direct blast effects, (2) mechanical causes associated with wreckage, (3) burns and (4) nuclear radiation. By far the greatest number of casualties would come from mechanical causes and burns, treatment for which would follow widely known medical practice. The most serious problems result from the great number of casualties in a short period of time and the fact that medical and first aid personnel are also likely to be among the victims.

"Effect of Bomb Blast on Power Stations During World War II" was the topic of **J. G. Noest,** division engineer of the Consolidated Edison Co. of New York. The speaker visited 30 power stations in Germany immediately after the end of World War II, and of these, 21 had suffered major bomb damage. Although the types of bombs and methods of attack may never be duplicated again, some lessons may be learned from the German experience. Up to September 1944 it was stated that repairs were made to plants about as rapidly as they were bombed out. To some extent damage was reduced by having the power plants shut down at the time of expected bombing. Also, because of the use of instantaneously fused bombs, destruction was often confined to the roof structure and overhead cranes. Had delayed-action bombs been used more extensively, damage would have been far greater.

Practically all damage was due to direct bomb blast, largely because of effective plant fire fighting. Cooling towers were easily put out of service because of their light construction. Loosely laid bricks were found effective in protecting transformers. For rotating equipment, such as turbines and pumps, protective barriers were made of reinforced concrete sectional arches. Up to the last few months of the war, destruction of power-consuming equipment was so great that reconstruction of power plants was able to keep abreast of demands of electric energy.

Progress in Electric Power

Tracing the electric power industry from its first generating station in the early 1880's to its present state of development, Messrs. **I. E. Moultrop** and **G. A. Orrok** proceeded to offer some predictions on future technical advances.

The engineering advances thus far, comprising a steady increase in unit sizes, in steam pressures and temperatures, as well as improvement in steam cycles, transmission and operating practice, had made possible a steady decrease in the average cost of electricity to the consumer over a period when the cost index of practically all other products had continuously risen.

Generally speaking, the authors contended that it is easier to build good and efficient equipment in the larger sizes than in the smaller sizes. This is because large units permit the employment of refinements that would have such minor effect in smaller equipment that they could not be justified.

Lessons of the past suggest that units of the future will show not only continued growth in size, but that major forward steps will come through further improvement in the cycle efficiency by employing still higher pressures and particularly temperatures beyond the present top of 1050 F; also, by reduction in the percentage of heat rejected in the condenser through by-product use or recirculated heat. To quote: "There is an immediate need for metallurgy in piping and equipment which will withstand 1200 F. . . . The tendency for higher and higher temperatures is a lesson for those who are planning the use of atomic energy for power purposes. Such energy must be used at a high heat level to be justified by the results; and atomic scientists should bend their efforts toward the conversion of high potential energy to power, rather than considering means to degrade energy to the point where it can be contained in conventional equipment."

The authors further suggested that, despite certain difficulties, it would seem that doubling or tripling present generator voltages would reduce the amount of copper in the machines, as well as reduce mechanical and cooling stresses.

As concerns switching and moving contacts, such as found in regulators, tap-changers and the switches themselves, it was believed that a completely new approach is desirable, and power switching of the future may be done electronically in tubes.

The need for cheaper underground distribution construction was emphasized, as well as the elimination of noise from transformers.

Generator Design Progress

E. D. Huntley and **H. D. Taylor** of the General Electric Co. presented a descriptive paper entitled "Progress in the Development of Large Turbine Generators." Contrasting 1950 with 1929, the authors noted that in the earlier year 60-cycle generators larger than 15,625-kva-rating were designed for 1800 rpm and that 62,500

kva was considered a large rating. Also, most of the generators were air cooled, while now practically all new machines for central-station service are hydrogen cooled. Today two-pole, 3600-rpm generators have undergone a ten to one size increase over 1929.

An extremely good record of reliability has been established during the first ten years of operating experience with hydrogen-cooled generators. A simplified hydrogen system known as the "Continuous Scavenging System" was developed several years ago. It eliminates the use of vacuum-treated oil, cuts down the number and size of auxiliaries and simplifies operation.

In the earliest hydrogen-cooled generators heavy split cast-steel end shields were employed. These castings proved to be rather expensive, were often porous and were difficult to manufacture. Several years ago a major improvement was made by changing end shields to fabricated construction, using welded steel plates.

Rotors of large turbine-generators are almost universally made of solid steel forgings. Alloy steel containing about 2.5 to 3 per cent nickel and fractional percentages of molybdenum and vanadium is often employed for rotors.

Two-pole generators running at 3600 rpm are somewhat bulkier, heavier and less efficient than four-pole 1800-rpm machines. However, to obtain the highest thermal efficiency and overall economy with steam turbines, it is necessary to use the highest feasible speed of rotation. This permits minimum diameter of turbine shells and the minimum number of stages.

The extension of rated 3600-rpm generator capacity from about 12,500 kva in 1929 to more than 125,000 kva in 1950 has involved a great many problems. Without hydrogen cooling and other improvements in ventilation the present high output would be impossible. The development of means to eliminate double-frequency vibration has also helped, along with improvements in field coil materials to resist thermal distortion and in the magnetic materials of both rotor and stator.

The authors noted that there are advantages in raising excitation voltage from 250 to 375 volts and in increasing generator voltage above the long-established 13,-800-volt level for 3600-rpm machines larger than 112,500 kva. In general, armature voltage should be higher as rating is increased.

Midwest Power Conference

The fourteenth annual Midwest Power Conference will be held April 4, 5 and 6, 1951, at the Sherman Hotel in Chicago.

This annual three-day meeting is sponsored by Illinois Tech and eighteen midwestern universities and professional societies. It attracts more than 3000 power engineers from all parts of the United States and Canada.

A ten-man industry committee aids Illinois Tech in planning and handling the conference. Its members represent different phases of the power industry. The director of the Conference is Prof. R. A. Budenholzer.

Fairmont Fuels Conference

SPONSORED by Fairmont Coal Bureau, this all-day Conference at the Philadelphia Engineers' Club on January 24 sought to bring consulting engineers, manufacturers of fuel-burning equipment and industrial power men together to consider the importance of incorporating fuel-burning flexibility in the design of industrial power plants, and of bringing the consulting engineer into the small plant operating picture.

At the morning session **Carl A. Marshall,** managing director of Fairmont Coal Bureau, who presided, asserted that more than half the bituminous coal consumed by industry is in plants that burn less than 10,000 tons yearly. Designating the industrial power engineer as "the forgotten man," he urged closer ties with the consulting engineer to the end that such plants be designed and operated so as to permit use of a wide range in fuel, which fact is becoming increasingly important in view of the present emergency. The new wage agreements with the miners' union, he predicted, would increase the price of coal to the consumer by about six per cent.

Purpose of Bureau Explained

E. C. Payne, of Pittsburgh Consolidation Coal Company, followed, giving a review of the Fairmont Coal Bureau which was started in 1938 and fully organized by 1942 with the backing of some twenty-five coal producers. The purpose was to interest and educate both coal users and equipment manufacturers in the burning of high volatile, low ash-fusion temperature coal from the Fairmont district and render service thereto. Since many small plants are not serviced by consulting engineers, it is one of the Bureau's aims to direct this type of business to the consulting engineer, to the end that small power plants may have the benefit of improved engineering.

The next speaker was **John Saxe,** chief engineer of Gibbs & Hill, well-known New York consulting engineering firm. For steam outputs of 50,000 to 300,000 lb per hr, he stated the continuous discharge spreader stoker is coming to the fore and has certain advantages over pulverized coal, including less power, more ready disposal of ash, and has comparable overall efficiency. However, although coal is the basic fuel, it is desirable to be able to convert to oil when conditions warrant, and this often dictates the selection of pulverized coal, since stoker-fired furnaces are more difficult to convert. For capacities up to 25,000 lb of steam per hour he regarded the single-retort underfeed stoker as the only solution.

Continuing, he observed that while the trend in large steam generating units is toward single-pass design, the multiple-pass design is desirable for small units, inasmuch as heat traps add considerably to the expense. Where used, however, air preheaters are generally preferred over economizers. In order to minimize operating labor it is desirable to place auxiliaries at the boiler operating level and to employ such automatic controls as can be economically justified; also sufficient instrumentation to provide a knowledge of operating results.

J. B. Laudig, speaking of the fuel consultation service for smaller consumers, stated that coal is often blamed for difficulties traceable to other causes. For small plants the tendency is now to use standardized boilers, and while designs that permit flexibility in fuel selection generally cost more, this can usually be more than offset by savings in the price of coal that it is possible to burn satisfactorily. Fuel supply studies, including freight rates, he regarded as a most important step in the design of a plant. Size consist of the coal is also important. Double-screened coal is uniform and does not absorb as much moisture; it is particularly suited to burning on underfeed stokers.

D. M. Given, of Fairmont Coal Bureau, spoke of oil competition with coal on the Eastern Seaboard. Oil in 1949 had reached as low as $1.60 a barrel as a result of which many utilities and industrials converted to oil. Although a large number of the utilities have now returned to pulverized coal, the problem of reconversion to stokers is not as simple for many small industrial plants. Lack of proper operating records in small plants makes it difficult to arrive at cost comparisons.

If a plant is well engineered, said Mr. Given, there is little difference, other than fuel price, between burning coal or oil. In this connection, the price of coal from the Fairmont District, delivered in the Baltimore and Philadelphia markets, has been running less than oil for the past year. He called attention to the fact that sometimes too elaborate coal-handling equipment for a small plant defeats the purpose, and then proceeded to outline a simple system that would serve the purpose in most cases.

Symposium on Case Histories

The afternoon session was devoted to a symposium on case histories to illustrate the reduction of operating costs through good engineering and cooperation. Representatives of three equipment manufacturers and three consulting engineers participated.

The first talk was by **Carl E. Miller,** of Combustion Engineering — Superheater, Inc., who stressed the advantages of standardized boiler designs for small plants. There is no question, he said, as to the flexibility of spreader stokers in burning a variety of coals, but the limitations are difficulty in carrying very light loads and the necessity of providing cinder collectors. For outputs up to about 35,000 lb of steam per hour the single-retort underfeed stoker has advantages in that it can readily carry light loads, it presents no cinder problem and it can do without fans.

He called attention to the fact that sizing of such underfeed stokers on a square foot basis may be very misleading, because width exerts a considerable influence.

Variations in burning rates with stoker width is a matter that should be discussed with the consulting engineer when the installation is laid out and the coal supplier should be consulted when the coal-handling equipment is selected.

Mr. Miller then showed slides and described the Perfection Stove Company plant at Cleveland as typical of a well-designed small stoker-fired plant.

The next talk was by **Fred Heller,** of Babcock & Wilcox Company, who described the modernization of the boiler plant at John Roebling Sons at Trenton, N. J. Here twelve old stoker-fired boilers were replaced by three 80,000-lb per hr pulverized-coal or oil-fired boilers designed for a load range of 4 to 1. At present oil is the standby fuel. Pulverized coal, with two mills per boiler, was chosen because of its flexibility in meeting load swings, the easy change to oil is desired and its ability to use high-temperature air. The units are designed for 650 psi, 750 F, and have been operating at approximately 85 per cent efficiency in contrast to 60 per cent for the old plant. The auxiliaries are steam-driven in order to provide exhaust steam for heating the plant. A pneumatic ash-conveying system and complete automatic combustion control are provided.

I. L. Nevells, of Westinghouse Electric Corporation, cited the case history of the Electric Storage Battery plant at Philadelphia. This was a case where a completely new plant was not justified but modernization consisted of replacing Murphy stokers in four old boilers by underfeed stokers in 1940, and the replacement in 1948 of one old unit by a new 35,000-lb per hr spreader-stoker-fired boiler. Since the plant is in the heart of Philadelphia, it became necessary to replace the static collector, and a non-friable $1^1/_4 \times {}^5/_8$-in. double-screened coal was substituted for the low-volatile friable coal formerly used. Moreover, there was a saving of 75 cents a ton in the coal.

The next speaker was **J. H. Rohrer** of Day & Zimmerman, Inc., Philadelphia consulting engineers, who selected the case history of the power plant serving a dyeing and finishing works. This contained two 500-hp, 200-psi, brick-set oil-fired boilers installed over twenty years ago. About ten years ago one of these was changed to pulverized coal with water-cooled furnaces.

By 1948 the load had increased to the extent that an additional boiler became necessary. Therefore a 75,000-lb per hr unit was selected, capable of carrying the entire plant load with the old boilers held in reserve. This unit has an efficiency of 85 per cent as compared with 75 per cent for the old units and is pulverized-coal-fired with oil as an alternate fuel. The coal is of the high-volatile, low ash-fusion variety and, at present Philadelphia market prices, is cheaper than oil.

P. H. Oppenheimer, consulting engineer of Westfield, N. J., next described and showed slides of a new steam heating plant for a large orchid nursery. Here 13 old boilers, mostly hand-fired and scattered among the hot-houses, were replaced by the new boiler plant containing three 20,000-lb per hr water-tube boilers fired by underfeed stokers. This type of stoker was

selected in preference to spreaders because of banking requirements. Only two units are required to carry the heating load and the third is standby. Steam is generated and transmitted at 125 psi and then reduced at various stations to 15 psi for heating. Condensate is returned. The coal-handling system is simple and includes a silo and screw conveyor. All auxiliaries are placed in front of the boilers so as to be visible to the boiler operator.

The new plant has effected a 23 per cent saving in fuel and 42 per cent saving in labor, with a total dollar saving of some $14,000 per year.

The last contributor to the symposium was **John E. Biery**, New York consulting engineer, who described successive steps in the modernization of an old boiler plant in Long Island City. This had contained four hrt boilers operating at 150 psi, but growth of steam and electric demand necessitated replacement of these old boilers with new units having a combined capacity of 130,000 lb per hr. Further manufacturing expansion in 1945 necessitated a 100 per cent increase in the power plant capacity in the same space, also a new stack. How this is being accomplished without interruption in service was explained by Mr. Biery. The expansion program involves four 60,000-lb per hr boilers and three additional 1000-kw vertical engine-driven generating units.

A final talk at the meeting was given by **Clair Shaeffer**, vice president of Rodie Coal Company, who related some interesting experiences of a coal and stoker salesman.

Attendance at the Conference exceeded 200.

New Lignite Laboratory

A new $750,000 Bureau of Mines lignite laboratory at Grand Forks, N. Dak., where experiments will be conducted to spearhead the way for greater use of the Nation's enormous lignite reserves, is now completed. The first laboratory to be built exclusively for lignite research, the new building provides facilities for studying methods of increasing the use of lignite for power, heat and other purposes for further development of the Great Plains and nearby states.

Designed with the safety, convenience and comfort of the staff in mind, the new laboratory features emergency escape exits, first-aid cabinets, fire-control facilities, "deluge" showers in corridors, safe storage for flammable materials and effective ventilation for protection against gases. Dedication ceremonies will probably be held in May.

Research will include studies in preparing and drying lignite to meet the demand for dried lignite that is expected to come from new power plants in the Upper Midwest.

Practically untouched, lignite reserves in the United States are estimated at 939 billion tons. Containing 600 billion tons, North Dakota mines 96 per cent or nearly 3 million of the Nation's yearly production. Eastern Montana also has about 315 billion tons of lignite.

Air Pollution Enforcement in Los Angeles

The Air Pollution Control District of Los Angeles County has just issued a most comprehensive annual report covering its 1949–1950 activities and the results attained. It includes the accumulated scientific and statistical data collected, together with administrative information on the air pollution control. Only a few high spots of this 48-page report will here be cited.

The work is carried on through a four-phase attack of inspection, enforcement, research and engineering. The Inspection Division locates the source of pollution; the Engineering Division secures data to determine the total emissions going to the atmosphere; and the Research Division collects samples for identification. To the date of the report, 1773 permits had been approved by the Engineering Division, of which 1207 were for new installations and 566 for control devices on equipment which if uncontrolled would have violated the regulations. In fact, more than six thousand sources that formerly emitted pollutants in excess of that permitted by law have been corrected.

Thirty-Five Per Cent Reduction

Since April 1948, air pollution in Los Angeles County has been reduced by approximately thirty-five per cent and, based on daily observations of the U. S. Weather Bureau, there has been a thirty per cent improvement in visibility. Moreover, concentrations of sulfur dioxide and trioxide have been reduced some fifty per cent.

These results have been brought about largely by controlling pollution at the source through the permit system, supplemented by the legal machinery of enforcement provided by law. To cite a few classifications where there has been a marked improvement, household incinerators have shown a 17 per cent decrease in violations; industrial and municipal incinerators 47 per cent; emissions from plants in the metals industry 22 per cent; food, rendering, fertilizer and paint industries 32 per cent; minerals and earth processing 27 per cent; and sulfur dioxide from sources other than the burning of fuel oil has been reduced 77 per cent. As yet information is not complete on sulfur dioxide from fuel oil burning, nor as to industrial gases discharged to atmosphere.

It has been established by the Research Division that a significant percentage of the sulfur dioxide in the atmosphere oxidizes to sulfur trioxide, and there is evidence that this acid mist could account for thirty to sixty per cent of the total reduction in visibility.

Oxidation of Sulfur Dioxide

A research project at the University of California at Los Angeles, which is sponsored by the District, deals with the oxidation of sulfur dioxide to sulfuric acid in the atmosphere. While this work is not yet complete, it has demonstrated that in the presence of solar radiation another mechanism is possible, involving

the photochemical action of light on sulfur dioxide according to the following steps:

A—SO_2 + sunlight→activated sulfur dioxide
B—Activated sulfur dioxide + $O_2 \rightarrow SO_3 + O$
C—$SO_3 + H_2O \rightarrow H_2SO_4$
D—$O + O_2 \rightarrow O_3$

The fact that particles between 0.5 micron and 0.8 micron have the ability to scatter the maximum amounts of light is well established. Particle size measurements on air samples show an increase in the number of particles in the 0.5 to 0.8 micron range as the visibility decreases. Although the identity of the particles that show the greatest increase in number has not been ascertained, persistent liquid droplets and sulfur trioxide are found in this group.

Comparatively large quantities of oil aerosols have been found in samples collected from the air. There are also oxygenated and nitrogenous materials associated with secondary oxidation reactions which appear to have eye-irritating properties and some crop-damaging effects.

With reference to public relations, the report states that the work is motivated by the firm conviction that an honestly and completely informed public is the strongest ally that a governmental agency can possess. Hence the policy has been adopted of disclosing all the facts, whether favorable or unfavorable, and securing the cooperation of all media of public information, including the press, civic organizations, television and radio.

The annual expenditures amounted to approximately $370,000.

British Power Stations

According to the British Electricity Authority's report for the twelve months ending March 31, 1950, as briefed by *Engineering and Boiler House Review* of January 1951, the total installed capacity of 293 Authority-owned power stations was 13,784,000 kw, which accounted for an annual output of more than 49 million kilowatt-hours. Capacity added during the year was close to a million kilowatts in 21 stations, and industrial consumption increased by 8 per cent, commercial by 10 per cent and residential by only 1.9 per cent.

More than a third of the units are 25 yr old or over, and about a half, representing 10 per cent of the total capacity, are rated below 8000 kw. Three-quarters of the generating capacity approved for installation in 1953–1955 involve units of 30,000 and 60,000 kw, although one of the new stations will have single-boiler-turbine units of 100,000 kw and employ steam conditions of 1500 psi, 1050 F.

The average thermal efficiency of the Authority's steam stations was 21.33 per cent.

The Grid System, operated by the Authority, comprised 5424 miles of main transmission lines of which about two-thirds operate at 132,000 volts.

There is still an acute shortage of power which, despite planned annual increases, is expected to lag behind demand for some years.

The Drying of Coal

The following notes are excerpts from a paper by W. R. Chapman and L. W. Needham which was delivered before several sections of the Institute of Fuel (Great Britain) during the period from January 3 to 15. The complete paper is descriptive of various types of driers and includes performance data, much of which concerns primarily the coal-producing industry and is therefore not here reproduced.

Where freezing of washed coal may present serious problems or where coal has to be transported long distances and freight charges are a major item, heat drying of the coal is becoming of considerable importance.

Bituminous coal, with an inherent moisture content of 1 to 15 per cent, is seldom dried for the sole purpose of increasing its calorific value. Lignite, however, with an inherent moisture content of 50 to 60 per cent, must have this moisture reduced to about 10 to 15 per cent if it is to be briquetted. This usually results in a reduction of the raw material to a fairly small size, the size degradation occurring partly by shrinkage and partly by disintegration as a result of the rapid evolution of water vapor.

Coal containing only inherent moisture usually appears dry and can be readily screened, bunkered, handled and transported; or, if its other properties are suitable, it can be cleaned by a dry process without difficulty. Some seams, however, are associated with considerable water, in which case it is virtually impossible to mine the coal in a dry state. Moreover, use of water for dust suppression underground results in the addition of small amounts of water to coals that otherwise would be dry.

Either or both of these circumstances may make it difficult to grade the coal by screening because damp coal causes "blinding" of screens in a most persistent fashion. The problem is to remove a few per cent of surface moisture, such treatment applying to coal not larger than about one inch in size; for in run-of-mine coal the surface moisture tends to be concentrated in the smaller sizes. Damp coals will usually screen satisfactorily at sizes above one inch, although difficulties may nevertheless arise in the subsequent treatment of the larger sizes if fine particles stick to them to an appreciable extent.

During recent years the use of dry processes for cleaning small coal has decreased on account of the introduction of water spraying underground. The problem of making damp coals fit for dry cleaning is essentially that of making them suitable for screening. Drying has therefore been adopted as a preliminary to dry cleaning in many instances.

When coal is pulverized for firing by the unit system, sufficient drying to permit fine grinding is usually obtained by sweeping the mill with hot air, which is then employed in transporting the coal to the burners and as primary air for combustion. The drying effect of the hot air is supplemented by the heat generated in grinding. External thermal drying, as a separate operation, is commonly confined to the bin-and-feeder system.

Freezing of Washed Coal

Washed coal below about $1^1/_2$ in. size, especially when fine coal is included, is likely to freeze in cars during cold weather, which makes unloading most difficult. Use of drying to avoid this difficulty is extending rapidly in the United States and Canada. To avoid freezing difficulties the free moisture content of washed coal, of $1^1/_2$ in.-0, must be reduced to about two per cent, or to a lower figure if the coal is smaller in size.

The economic aspect of thermal drying, from the standpoint of freight charges, arises where washed coals are subject to long haulage—a problem of little importance in England. The solution is to balance one cost against the other. When coal is subject to long hauls, drying to below two or three per cent of free moisture may lead to excessive dust losses through action of the wind.

With the exception of lignite, the commercial drying of coal is confined to the removal of all or part of the surface moisture that has been added at some stage subsequent to the actual mining, such as spraying for dust suppression. This moisture is in excess of that which the coal would normally contain after exposure to the surrounding atmosphere. Owing to the porosity of coal and the presence of internal surfaces, which play a large part in the absorption of water, it is not easy to define the condition of freedom from surface moisture; for the moisture content of an "air-dried" coal will depend upon the humidity of the atmosphere with which it is in equilibrium.

Commercial Practice

Except for brown coals it is usually uneconomic to dry coal to a lower moisture content than that representing its "air-dry" condition. In fact, commercial driers often leave one or two per cent of unwanted moisture in the dried product, because the sensible heat of the coal can be utilized to remove this residual moisture, provided opportunity is presented for the escape of the water vapor.

The essential factors involved in coal drying are: (*a*) the initial moisture; (*b*) the desired final moisture; (*c*) the physical condition of the coal, particularly its porosity; and (*d*) its chemical nature as reflected in its liability to surface oxidation and spontaneous combustion. The physical condition affects the initial moisture content, the ease with which the moisture can be removed, and the degree of unifor-

mity of moisture in the final product. The chemical nature of the coal is also of importance if the dry coal is to be used for coking.

Dust Removal

One of the principal problems in coal drying, as well as a source of considerable expense in both equipment and power consumption, is that of the removal of dust from the exhaust gases. Various kinds of cyclone collectors have been employed in conjunction with driers, and the final removal of dust from the waste gases by perforated tubular baffle-plates, by water scrubbers or sprays, or by electrostatic precipitation, is frequently necessary.

Corrosion in dust collectors, due to condensation and the formation of acid waters, is the cause of heavy maintenance. This has been met in Belgium by using stainless-steel cyclones, and in Germany dust-collecting cyclones lined with shaped tiles of cast basalt have been widely used; they also resist abrasion.

Eighteenth Annual E.C.P.D. Report

The Engineers' Council for Professional Development is a conference organized to enhance the professional status of the engineer through cooperative efforts of eight engineering societies. Its work is of an inter-society, intra-professional character. H. S. Rogers, president of the Polytechnic Institute of Brooklyn, is chairman of E.C.P.D. for 1950–1951. Two engineers well known in the steam power field are currently serving as active chairmen of E.C.P.D. Standing Committees: W. F. Thompson of Westcott & Mapes, Inc., on the Guidance Committee, and William F. Ryan of Stone & Webster Engineering Corp. on the Ethics Committee.

The Eighteenth Annual Report tells of some of the ways in which E.C.P.D. is working to improve the methods by which a person becomes an engineer. An important activity of this past year was the presentation of a six-point program proposed by the Committee on Professional Training to aid the young engineer during his first five years of professional development. The program recognizes two cardinal principles: that the final responsibility for professional advancement rests squarely upon the individual's shoulders, and that the engineering profession must provide the young engineer with both the opportunity for development and a favorite climate in which to grow. The areas of professional development which the six-point program covers are as follows: (1) orientation and training of the young engineer, (2) continued education of engineering graduates, (3) integrating the young engineer into his community, (4) registration of the young engineer, (5) self-appraisal methods for valuable characteristics in engineering and (6) selected reading.

The Committee on Engineering Schools prepared a report entitled "Differentiating Characteristics of an Engineering Curriculum." In considering the differences in characteristics between the engineer and a person in an adjoining field the

ability to design was found to be a significant and distinctive element. The Committee formulated this statement:

"An engineer is characterized by his ability to apply creatively scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct and operate the same with full cognizance of their design, and of the limitations of behavior imposed by such design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation, and safety to life and property."

In order to train a man to become an engineer the curriculum must furnish the technical background and also the general training for the process of analysis and synthesis essential to designing. While it is not essential that one must be engaged in design in order to be an engineer, it is important to have a knowledge of design, based on the application of scientific principles.

By design is meant the whole creative process, extending from the initial conceptual thought to the subsequently refined final plan. It involves within the student the development of original, resourceful, creative ability.

Probably the best known achievement of E.C.P.D. is the accrediting work of the Committee on Engineering Schools. The first inspections were carried out during the academic year 1935–1936. As of October 20, 1950, there were a total of 656 accredited curricula offered by 142 engineering schools.

Combustion of Industrial Fuels

A conference on this subject is to be held at the University of Michigan, Ann Arbor, on March 21 and 22, under the sponsorship of the College of Engineering. It will include the combustion of solid, liquid and gaseous fuels in industrial applications and is intended to draw technical men from the utilities, industry, research and educational organizations of Michigan and adjoining states. An effort has been made to include material which will also be of interest to the designers and operators of medium and small industrial power and heating plants. This objective will probably be accomplished by including some additional papers on design of plants and choice of fuels, and on more efficient utilization of fuels in existing plants. A tentative outline of the program follows:

March 21—Wednesday morning

8:30–9:30 Registration.

9:30 Fuel to be discussed—Gas.
Chairman—Prof. A. H. White
Welcome—Dean Ivan C. Crawford.

"Industrial Gas Furnaces," by Donald Beggs, Surface Combustion Corp.

"Heating of Industrial Furnaces by Radiation from Gas-Fired Tubes," by Lee Wilson.

March 21—Wednesday afternoon

Fuel to be discussed—Coal.

Chairman—Julian E. Tobey.
"Cyclone Furnaces," by W. H. Rowand, Babcock & Wilcox Co.
"Better Engineering for the Small Steam Plant," by Earl C. Payne, Pittsburgh Consolidated Coal Co.
"Evaluation and Purchasing of Coal," by R. J. Brandon and M. Pease, Detroit Edison Co.

March 21—Wednesday evening

6:00 Dinner at Union.
Chairman—Professor Hugh E. Keeler.
"Some of the Problems in the Industrial Application of Atomic Energy," by G. G. Brown, Chief Engineer, Atomic Energy Commission.
Technical Film, available from Combustion Engineering-Superheater, Inc.

March 22—Thursday morning

Fuel to be discussed—Oil.
"Burner Testing of Fuel Oils," by Bruce R. Walsh, Gulf Research and Development Co.
"Some Combustion Problems When Burning Heavy Industrial Fuel Oils," by Oliver F. Campbell, Sinclair Refining Co.

March 22—Thursday afternoon

1:30 Subject—Smoke Abatement.
Chairman—Prof. R. Clay Porter.
"Meet the Smoke Inspector," by a representative of the Division of Air Polution, City of Detroit.
"Gas Analysis for Better Combustion," by C. H. Barnard, Bailey Meter Co.
"Theory and Practice of Steam Air Jets for Improved Combustion."

Inquiries concerning the Conference should be addressed to the Institutes Dept., Extension Service, University of Michigan, Ann Arbor, Mich.

Personals

Edward L. Champion, vice president of Gibbs & Hill, New York firm of consulting engineers, since 1940, has recently assumed charge of that company's Los Angeles Office, located at 510 W. Sixth St.

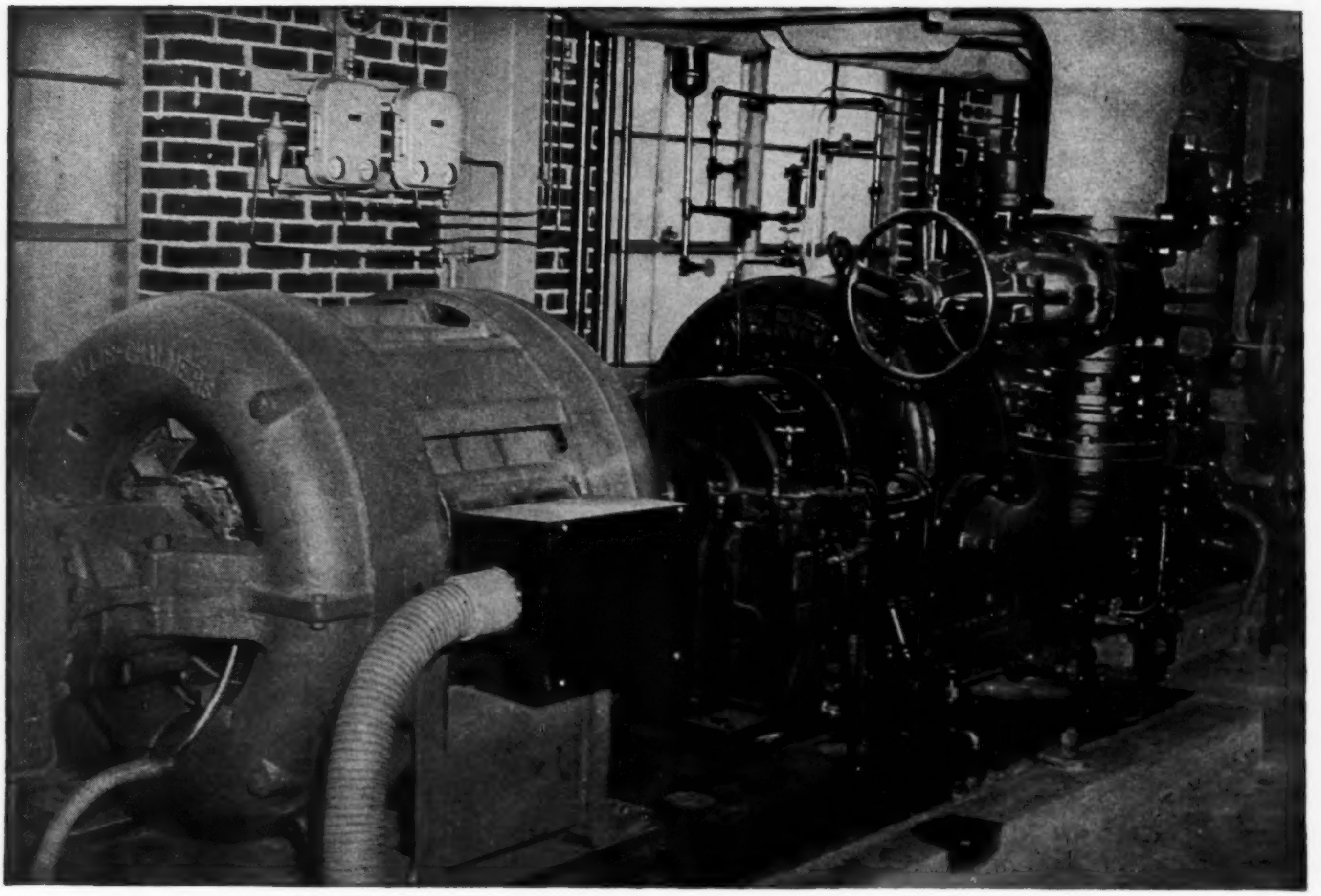
Edward R. Lee, Jr., formerly with J. G. White Engineering Corp., has joined The Kissick Co., New York and Philadelphia, as sales engineer handling Copes, Vulcan and Connery accounts.

J. R. Stover has been made chief electrical engineer of the New York State Electric & Gas Corp., succeeding W. W. Perry, who recently retired.

Frank Sutton has given up his own consulting engineering firm and joined the staff of Guy B. Panero, engineers of New York and Washington.

Isaac Harter, chairman of the board of The Babcock & Wilcox Tube Co., was awarded the Newcomen Medal "for achievement in the field of steam" at a joint meeting of the Newcomen Society and the Franklin Institute on January 17.

The TERRY TURBINE



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This 200 kw Terry Turbine driven generating unit operates in parallel with other generating equipment, the load on the unit being adjusted in accordance with the demands for exhaust steam. It is a single stage axial-flow, type, 4500/1200 rpm, 160 psi, 0 superheat, 5 psi back pressure, equipped with Terry reduction gears, oil-relay governor, motor synchronizer and back-pressure regulator.

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REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Principles of Engineering Economy

By Eugene L. Grant

The Third Edition of this well-known engineering text continues the practice of stressing the question, "Will it pay?" in considering economic alternatives of technical projects. Although the general plan of organization has been maintained and places major emphasis on techniques for economy studies, more than two-thirds of the book has been rewritten.

New material has been added which discusses the treatment of prospective price changes, something which assumes considerable importance in engineering planning of the present. The chapter on theoretical aspects of replacement economy has been revised in accordance with an approach developed by George Terborgh of the Machinery and Allied Products Institute. New chapters have been added entitled "The Relationship of Income Taxes to Economy Studies" and "Further Examples of Economy Studies in Manufacturing Industries and Public Utilities."

There are many new problems, bringing the total to 400. Of these about 30 per cent have answers, making the text useful for self study.

Composed of 623 pages the book sells for $5.

Modern Air Conditioning, Heating and Ventilating

By W. H. Carrier, R. E. Cherne and W. A. Grant

The late Willis H. Carrier, one of the pioneers of the air-conditioning industry, was assisted by R. E. Cherne, consulting engineer, and Walter E. Grant, director of research, Carrier Corp., in the preparation of the Second Edition of this comprehensive work. Bringing up to date changes which have occurred within the past ten years, the book is based largely upon data developed and used by the Carrier Corp. in training technical graduates for application-engineering assignments.

Covered in the 21 chapters are such subjects as psychrometrics and comfort, techniques of estimating, heat-producing and heat-distributing equipment, steam and hot-water heating systems, fans and heaters, air-cleaning devices, cooling and humidification, refrigeration systems, automatic controls, and application practice. Some new features of the Second Edition include oil-burner applications, engineering data on panel heating, new techniques in air cleaning and purification, basic data for cooling coils, and a functional analysis of central conditioning systems. To add to the value of the book as a teaching aid a series of problems covering both theory and practice has been added. In the Appendix there are 35 tables covering a wide range of data useful in making air-conditioning calculations.

The book is 7 × 10 in size, contains 574 pages and sells for $10.

Progress in Coal Science

Edited by D. H. Bangham

During the years 1943 to 1947 the British Coal Utilisation Research Association circulated privately a series of articles in its Monthly Bulletin. Of these 26 are now available in this book under four different headings: Modern Experimental Techniques, Fine Particles, Organic Chemistry of Coal Products, and Chemical Aspects of Combustion and Gasification.

Each chapter contains a bibliography with references to American and continental European literature as well as British sources. The emphasis of the book is primarily toward the interests of research workers in fuel technology, as can be deduced from some of the chapter titles: Crystallographic Techniques in Chemical Analysis, Chromatographic Adsorption Analysis, Photographic Techniques in Combustion Research, Particle Size Measurement, Grindability of Coal, Occurrence of Rare Elements in Coal Ashes, Action of Chemical Reagents on Bituminous Coal, Hydrocarbon Synthesis, Combustion in Fuel Beds, and Recent Developments in Gasification.

There are 456 pages and the book sells for $7.

Safety in Electric and Gas Welding and Cutting Operations

The American War Standard on safety in welding and cutting proved so valuable in minimizing lost-time injuries and property losses, which might have occurred because of accelerated production rates and the use of untrained personnel, that it was decided to prepare an American Standard on the same subject. With industrial production on the increase again, issuance of the new American Standard "Safety in Electric and Gas Welding and Cutting Operations" is especially timely. It was prepared by a committee sponsored by the American Welding Society under the procedures of the American Standard Association, and reflects the best recommendations of welding engineers, safety engineers, equipment manufacturers, insurance organizations, labor organizations and governmental labor agencies, all of whom were represented on the Committee.

Covered are regulations for the safe installation and operation of welding equipment for all arc, gas and resistance welding processes. Provisions are included for fire prevention and protection in regularly assigned welding areas and in other locations, as well. The protection of personnel is covered from the standpoint of the welder, for whom eye protection and clothing requirements, health protection, etc., are prescribed, and from the standpoint of other workers in areas adjacent to welding operations.

Precautions are specified for the welding of materials which may give off toxic fumes and for welding in confined spaces, and the ventilation requirements should be of particular interest.

Copies of this Standard are available at 50 cents each from the American Welding Society, 33 West 39th Street, New York 18, N. Y., or the American Standards Association, Inc., 70 East 45th Street, New York 17, N. Y.

Manual of Instrument Transformers

The theory of operation and the application of instrument transformers are covered in an illustrated 76-page manual prepared by the Meter and Instrument Divisions of the General Electric Co. The manual discusses the basic fundamentals of instrument transformers, including accuracy, standards, insulation and polarity. It also provides information on potential and current transformers, covering operating principles, types and ratings, applications, circuits and fusing. Also included are a chart for selecting the proper transformers for a specific application and a bibliography covering various phases of instrument transformer operation, design, application and performance.

The manual is designated as GET-97A and may be obtained from the Apparatus Department, General Electric Co., Schenectady 5, N. Y., for $1.

Radiation Monitoring in Atomic Defense

By D. E. Gray and J. H. Martens

Current interest in civilian defense programs makes this book especially timely. Part I is devoted to background information on atomic and nuclear energy and the hazards that are produced during and after an explosion. Much of this section can be understood by readers with no technical background. Consideration is given to protective measures and to means of measuring and detecting nuclear radiations.

Part II takes up instruments and equipment in radiation detection. It describes the basic construction and characteristics of a number of specific radiation detection devices and gives instructions for their operation and maintenance.

Regarding the authors, Dr. D. E. Gray is chief of the Navy Research Section of the Library of Congress, and J. H. Martens is associated with the Technical Information Service of the Atomic Energy Commission.

The book has 122 pages and sells for $2.

Flexitallic Gasket Co., Camden, N. J., announces the addition of three new distributors and two new agents. The distributors are the Tate Engineering & Supply Co., Baltimore; A. L. Crump & Co., Chicago; and Carl Grimes & Co., Des Moines, Ia. The new agents are Frank Valetti & Co., Philadelphia, covering the marine industry in that district, and Southern Marine Supply Co., Inc., Savannah, Ga.

Whiton Machine Co., New London, Conn., has appointed Evan Price as manager of its turbine sales. Mr. Price was formerly in charge of turbine sales for The Kissick Co. of New York.

Obituaries

Charles E. Joos, vice president of the Cochrane Corp., Philadelphia, died on January 7 at his home in suburban Wyncote, after a long illness at the age of 54. He had been associated with the Cochrane organization for 25 years and was widely known as an authority on water treatment, on which subject he was an occasional contributor to COMBUSTION.

Oscar C. Merrill, formerly executive secretary of the Federal Power Commission and widely known some fifteen years ago as chief U. S. Government representative for the World Power Conference, died at Bethesda, Md., on Jan. 15. He was 76 years old and, prior to his connection with the Federal Power Commission, had been chief engineer of the U. S. Forest Service.

Business Notes

De Laval Steam Turbine Co. has appointed W. A. Neumann, Jr., as manager of its IMO-Products Division. He has served as acting manager of this division for the past year.

Northern Equipment Division of the Continental Foundry & Machine Co., Erie, Pa., has made William L. Hunter vice president in addition to general manager, the position which he has held for some time.

General Electric Co. has named John W. Belanger of Schenectady and Nicholas M. Du Chemin of Lynn Field, Mass., as general manager of the Large Apparatus and Small Apparatus Divisions, respectively. Marketing operations for all products of these departments will continue under Chester H. Lang, company vice president.

Edward Valves, Inc., East Chicago, Ind., has promoted William G. Mahlman from supervisor of order analysis to sales office manager. He succeeds Herbert J. Rowe who has been called back to the U. S. Marine Corps.

Tube Turns, Inc., has appointed the Bethlehem Supply Co., Tulsa, Okla., and the Bethlehem Supply Co. of California, Los Angeles, as distributors of Tube-Turn welding fittings and flanges.

C. H. Wheeler Mfg. Co., Philadelphia, a division of Hamilton-Thomas Corp., has appointed F. L. Yetter senior vice president. He was with the C. H. Wheeler Mfg. Co. in various capacities from 1916 to 1949, at which time he resigned the post of vice president and assistant general manager.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York, 16, N. Y.

Feedwater Control

A 16-page bulletin published by the Bailey Meter Co. describes the latest developments in Bailey three-element, air-operated feedwater control. The bulletin contains an easily understandable, concise discussion of problems encountered in controlling feedwater. Diagrams, cutaway views, typical chart records and photographs of modern installations are used to aid in describing the control system.

Spray Nozzles

Recooling spray nozzle systems for use in plants which operate condensers or use large quantities of water for cooling are pictured and described in Bulletin 6A-SP recently issued by Schutte and Koerting Co. The eight-page bulletin details design, application, construction and operation of SK spray nozzles and diagrams typical spray pond arrangements. Sizes, dimensions, capacities and spray nozzle patterns are included in tabular form for each nozzle size.

Soot Blower

Bulletin 485 prepared by the Vulcan Soot Blower Division of Continental Foundry & Machine Co. describes the Vulcan P-3 rotary soot blower head. Originally developed for the marine field, this head is now made available for stationary boiler cleaning. The four-page bulletin includes a photograph of the soot blower head and diagrams showing simplicity of maintenance.

Water Conditioning

The manner in which Allis-Chalmers No. 160 series corrosion inhibitor acts by neutralization and by surface adsorption to control the corrosion of steam and condensate lines is described in a leaflet released by the Allis-Chalmers Manufacturing Co. The corrosion inhibitor is a mixture of organic amines selected according to volatility characteristics required by each steam condensate system.

Steam Specialties

The C. E. Squires Co. has prepared a 33-page catalog containing descriptive matter on steam and air traps, pressure reducing valves, pump governors, pressure regulators, boiler feed controls, and temperature regulators. Also included are data for sizing this equipment, such as trap capacity tables, selection charts for reducing valves, and tables of reducing-valve capacities.

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